The Marine Laboratory

INSTITUTE OF MARINE SCIENCE
OF THE
UNIVERSITY OF MIAMI

Technical Report
June 1961

THE BIMINI INSTALLATION
to
U.S. Department of the Navy
Office of Naval Research
Biology Branch, Contract Nonr 840 (13)
Acoustics Branch, Contract Nonr 840 (16)
Bureau of Ships
Applied Sciences Branch, Contract Nobs 84540
Sonar Branch, Bell Telephone Laboratories
Purchase Order, D-602526
Based on Prime Contract Nobsr 57093

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MIAMI 49, FLORIDA

THE MARINE LABORATORY
Institute of Marine Science
University of Miami

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THE BIMINI INSTALLATION

1. Abstract.

A two-hydrophone cable assembly was installed on the ocean bottom off the west coast of Bimini, Bahamas on 9 November, 1960 by The Marine Laboratory, University of Miami. The cable was terminated in the Lerner Marine Laboratory, Bimini, by magnetic tape recording and analyzing equipment. The installation was made in order to study marine animal sounds under natural conditions, ambient noise, and sound propagation across the Straits of Florida. Preliminary observations indicate the presence of a variety of marine animal sounds and propagation conditions of theoretical and experimental interest.

2. Introduction.

A hydrophone-cable assembly has been installed on the east bank of the Gulf Stream with the cable terminating in the Lerner Marine Laboratory on Bimini, Bahamas. The assembly contains two hydrophones located on the bottom. One is a mile from shore in water 17 fathoms deep. The other one is in 200 fathoms of water about two miles from shore. A nominal frequency range of 10 to 12,000 cps is provided by the assembly.

The installation was made in connection with a study of the feasibility of using hydrophones to obtain information on marine animals in natural surroundings. It is also being used for studies of the effects of such oceanographic factors as surface waves, temperature versus depth and internal waves on sound propagation and ambient noise.

The operational procedure for the present, is to record the output of each hydrophone on magnetic tape. The tape is played back through earphones or loud speakers, at speeds up to eight times the recording speed. Observers note the occurrence of sounds of possible marine animal origin and retain recordings of such sounds for further study.

Recordings of samples of ambient noise are also made for study and analysis. In addition, graphical records of the noise levels at each hydrophone are made on a 24 hour basis. Preliminary propagation tests from Fowey Rocks on the west bank of the Gulf Stream to Bimini on the east bank, are being made. The objective is to carry on continuous measurements of propagation between the two points along with continuous ambient noise measurements.

It is planned to continue the above program for several months in order to obtain a statistical picture of the occurrence of events of

interest and to observe cyclical trends. Based on the information obtained, specialized programs with specialized equipment may be undertaken on subject matters of interest.

The work on marine animal sounds is supported in part by the Biology Branch of the Office of Naval Research and in part by Bell Telephone Laboratories under a contract with the Sonar Branch of the Bureau of Ships. Work on sound propagation and ambient noise is supported in part by the Acoustics Branch of the Office of Naval Research and in part by the Applied Sciences Branch of the Bureau of Ships. Laboratory space and facilities are provided by the Lerner Marine Laboratory, a Field Station in Biology of the American Museum of Natural History. The following factors entered into the selection of Bimini for the installation: the relatively short cable length required to reach the waters of the Gulf Stream; the clarity of the water; the availability of the Lerner Laboratory; the island's easy accessibility from Miami.

This report is intended to describe the characteristics of the system and the installation procedure, which involved some special techniques. The aim is to include enough detail to provide information for individuals concerned with the system or the results obtained. A summary of the preliminary observations is also given.

3. Overall System.

A chart of the area between Miami and Bimini is shown in Figure 1. Depth readings are in fathoms. The west coast of Bimini may be seen in more detail in Figure 14, along with the hydrophone locations.

A schematic outline of only the major functional capabilities of the fixed system installation at Bimini is contained in Figure 2. More detailed information appears later in the report under sections 4, 5, and 6.

4. Hydrophones and Preamplifiers.

(a) Hydrophones

Two PZT (lead zirconate) hydrophones, type 2Z-110, serial numbers 2Z-113 and 2Z-116, and associated preamplifers, were supplied by the Bell Telephone Laboratories, Whippany, New Jersey. They are encased in stainless-steel protective cages which also contain the transistorized preamplifiers. Fiberglass screening was wrapped around the cage to reduce the flow of water over the hydrophone and the resulting flow noise.

The active element of the hydrophone consists of two series connected lead zirconate crystal rings. The rings are cemented to metal end pieces with epoxy resin. The end piece which serves as a

base, has compression fittings for passing the leads, and the opposite piece has a small capillary tube for pressure equalization. The whole assembly is covered with a rubber boot and the interior filled with silicone oil. Capacitance is 0.051 μf.

Sensitivity versus frequency is shown in Figure 3, where sensitivity is expressed as the output of the hydrophone in db below one volt for 1 ubar of applied pressure. Frequency response measurements were made in a pressure tank to a frequency of 100 cps. The mean of this curve was extrapolated out to 2000 cps to provide a basis for system response calculations.

(b) Preamplifiers

(1) The transistorized preamplifiers are mounted as an integral part of the hydrophone assembly to provide proper impedance matching from the hydrophone to the cable and shore termination. The preamplifier gain is a fixed +40 db with a flat response from 30 to 2,000 cps and within $\pm$ 1 db from 20 to 5,000 cps. The preamplifier has an extremely low current requirement of 1.2 ma which is supplied from shore via a single pair of leads which simultaneously carry the hydrophone preamplifier output signals.

The preamplifiers are expected to have a useful life of two to three years under the present environmental conditions, with the possibility of lasting much longer. Transistors were selected for uniformity and stability, and prototype amplifiers were operated continuously for two months without exhibiting any noticeable deterioration of performance.

(2) Circuits. The circuit diagram is contained in Figure 4. Two 2N167 transistors provide two gain producing stages and the 2N123 serves as an emitter follower output stage providing low output impedance. High input impedance is maintained by applying a.c. feedback to the emitter of the input stage and d.c. feedback through the input stage bias resistor and the feedback loop. Large emitter resistors with bypass capacitors provide stabilization. The 0.005 μf capacitor in the collector circuit of the input stage suppresses high frequency parasitic oscillations which may occur with open input.

The preamplifier has a nominal rating of 1.2 ma at 20 vdc, but will function satisfactorily using supply voltages from 8 to 35 vdc. The supply voltage of course, affects the maximum signal handling capability.

The preamplifiers require 150 ms to recover from a 30 db overload and 700 ms to recover from interrupted power.

(3) Characteristics. Preamplifier self noise, which is plotted in Figure 5, was measured at the amplifier output, with the input shunted by a capacitance equal to that of the hydrophones. It is expressed as the equivalent per cycle voltage at the input, in db from one volt. The expected minimum ambient sea noise, correspondingly expressed as an equivalent input voltage, shown in Figure 5, indicates that below 10

cycles amplifier self noise rather than sea noise sets the limit for minimum signals.

The dotted curve of Figure 6, shows the maximum input voltage level at which limiting of the output voltage begins. The solid curve shows the dynamic range, i.e., the maximum input voltage minus the sum of the self noise and the expected minimum sea noise.

5. Cable.

(a) Description

The inshore end of the cable consists of 3800 feet of heavily armored four (4) conductor cable of approximately 1.25 inch diameter, which is joined through a splice box (see Figure 7) to two lengths of type PBW-0216 2 conductor armored distribution wire of approximately 0.3 inch diameter. One length of PBW, 2600 feet, is connected to the shallow hydrophone. The other length, 10,600 feet, is connected to the deep hydrophone. The electrical characteristics of the quad and the PBW cable are similar and the characteristics below apply equally to both cable types.

(1) Resistance 51.9 ohms/loop nm.

(2) Capacitance 0.0983 µf/nm.

6. Laboratory Equipment.

(a) Functional Description

The block diagram, Figure 8, illustrates the various functions which the shore-based equipment can perform. The following enumerates some of the system's features:

(1) Transistorized, battery operated, variable gain terminal amplifiers which terminate the cable through matching transformers.

(2) Oscillator, meter and attenuator for reference calibration signals.

(3) A two track tape recorder with continuous monitoring capability.

(4) Capstan drive power from an external, precision fork controlled amplifier.

(5) Provision for "dubbing" from the two track monitoring recorder to an external recorder or vice versa from any suitable external source.

(6) Special amplifiers and chart recorders for obtaining graphical records of ambient noise on a continuous basis.

(7) Two channel audio monitoring equipment.

(8) Filters for use while recording or monitoring.

(b) Terminal Variable Gain Amplifiers

These amplifiers are quite similar to the preamplifiers, and are assembled on phenolic printed circuit boards which plug into printed circuit connectors. The circuit diagram for the amplifiers, which are identical, is shown in Figure 9.

Self noise is plotted in Figure 10.

Maximum input voltage level and dynamic range versus frequency are plotted in Figure 11.

In general, the preamplifier description in paragraph 4b(2) applies to the terminal amplifiers.

Attenuators covering a range of 0 to -38 db in calibrated steps of 2 db are used at the input to the amplifiers. The amplifier has two fixed gain selections, i.e., +20 db and +40 db, which in conjunction with the attenuator, provide a variable amplifier gain from -18 db to +40 db in 2 db steps.

(c) Monitor Amplifier

This two channel amplifier is rack mounted and consists of conventional vacuum tube operated amplifier stages. There are separate volume controls for each channel and ganged controls for bass and treble adjustment.

The monitor reproduces the output from the record-play amplifier (RPA) during the record or playback mode from either track or both tracks simultaneously.

(d) Two Track Recorder

The two track recorder is mounted on the equipment rack and has a 14 inch reel capacity for 12-hour continuous recording at 1 7/8 ips, using 1 mil tape. Speeds of 3 3/4, 7 1/2 and 15 ips are also available with proportionate reduction of recording time.

(e) Rerecording Circuits

The output of each tape amplifier, in record or playback mode is terminated in phone jacks on the front panel.

The RPA outputs are supplied via cathode followers which

provide a low impedance path compatible with input requirements of most existing reproducing devices.

(f) Overall System Characteristics

The system response versus frequency from sound pressure at hydrophone to input of the terminal amplifier is plotted in Figure 12. It refers to the level in db below 1 volt at the amplifier input produced by a sound pressure of 1 microbar at the hydrophone. To obtain the response, the hydrophone was replaced by an equivalent capacity and a small series resistance. A known voltage was introduced across the resistance and the corresponding voltage measured at the terminal amplifier input. The measurements were made just before installation and the actual preamplifiers, cable lengths, transformers and terminal amplifiers were used. The hydrophone calibration shown in Figure 2 was assumed to be valid to 10,000 cps.

Figure 13 shows the relative system response including the record-reproduce loss for a tape speed of 1 7/8 ips. It was obtained by correcting the system response of Figure 12, for the loss as measured with arbitrary gain settings of the record and reproduce amplifiers.

In order to complete the picture of system response it is necessary to consider the record and playback characteristics of any external device employed in playback or analysis.

(g) Miscellaneous

(1) Ambient Noise Monitoring

Four Esterline Angus chart recorders, two for each hydrophone, are used to record ambient noise levels on a 24 hour basis. They are operated with a chart speed of three inches an hour and a full scale deflection of one milliampere. Currently, noise levels in the full frequency band of the system and in a 15 to 2,000 cps band are being recorded for both hydrophones.

(2) Filters

Provision has been made to install one or more variable frequency selective filters to be used during monitoring and playback.

7. Installation Procedure.

(a) Cable Assembly

The usual installation procedure is to lay the hydrophones at the desired location and pay out cable toward shore. Since the points at which the hydrophones were to be placed were not critical, it was

decided to lay the cable from the shore outward. This obviated the possibility of not having enough cable to reach shore, simplified the navigational procedure and enabled continuous monitoring of the hydrophones from shore during the laying operation.

The cable was wound on a steel reel six feet in diameter and four feet wide, that was mounted on two steel tripods. The deep and shallow hydrophones and associated lengths of distribution wire were assembled and wound on the reel. The overlapping portions of the two lengths were taped together. The armored cable was connected to the pair of distribution wires and wound over them. All connections were made and the assembly was completed and tested so that the laying could be carried out as a continuous operation.

Splicing the distribution wires to the armored cable was considered to be the most vulnerable of the assembly operations. When a splice was completed, there was no available way of telling beforehand, whether or not it would be short circuited from sea water seepage. The conductors were joined by means of crimped sleeves and wrapped with both polyethylene tape and D.R. tape. Such a splice, called a wet splice, is exposed to the sea water but is relieved of tension by the splice case. Also, there was no available way of testing for failure of the splice case to carry the tension of the armor wires.

The reel and cable assembly, weighing about 6000 pounds, was mounted on the after deck of the R/V LORD KELVIN, a vessel chartered from the Marine Acoustical Services, Inc., Miami. It is a converted subchaser 112 feet long, with adequate deck space for a reel, twin screws, and a relatively shallow draft of 6.25 feet.

(b) Cable Laying

With the R/V LORD KELVIN anchored a few hundred feet from the shore line of the Lerner Laboratory property, the end of the four conductor armored cable was taken ashore with the aid of a light line and a small boat. After the cable was secured, audio monitoring circuits connected to each pair of conductors indicated that both hydrophones were operative. Paying cable over her stern, the R/V LORD KELVIN then proceeded toward a marker buoy indicating the desired location for the shallow hydrophone. By idling the engines and braking the reel, some control over cable payout could be maintained. It was desired to lay the heavy cable with a slack factor of 10% and the light distribution wire with a factor of 25%. With the aid of footage marks on the cable and a knowledge of the ships position, this was accomplished approximately.

The shallow hydrophone was released about one mile from shore at a marker buoy and the deep hydrophone was released a mile farther out. The hydrophones were monitored throughout the operation and it was reported that six minutes were required for the deep hydrophone to fall 1200 feet from the surface to the bottom.

On the day after the laying was completed, the cable was viewed

from shore outward by means of a glass bottomed boat and window buckets. With an overhead sun, it was possible to follow the cable to depths of sixty or seventy feet. It lay in a straight line except for some slack at the splice box and was covered by sand in a few places. At about seventy feet, the depth began to increase markedly and the bottom and cable was lost from view before the shallow hydrophone was reached. Later, it was found in a large clear patch of white sand at a depth of 100 feet by scuba divers. The hydrophone was covered with a layer of sand and left in place. The bottom, from shore to hydrophone, consists of clear white sand with occasional patches of greenish-brown marine growth and flat outcroppings of limestone.

(c) Position Determination

As the R/V LORD KELVIN payed out cable, her range and true bearing from a midpoint on the shore line of the Lerner Laboratory property was obtained with a range finder and pelorus. The observations, read at intervals of two or three minutes, were radioed to the boat and tabulated with depth as read from a direct reading fathometer.

The pelorus consisted of a circular scale and pointer attached to the range finder from which the angular setting could be read. North was determined by setting the range finder on the North Star. The range finder, a split field type, was one meter in length. For distances up to two miles, range could be read to within 300 feet and bearing to within one degree.

Position was also obtained aboard the R/V LORD KELVIN, from sextant readings of the angles between Entrance Point and the Lerner Laboratory and between the Lerner Laboratory and Paradise Point.

The path of the cable ship and hydrophone positions obtained with the two methods are shown in Figure 14. The observations are in good agreement up to the position of hydrophone A. The differences in the observations beyond are larger than one would expect and a satisfactory explanation for them has not been found.

Recently, determinations of the hydrophone positions were made from travel time measurements of sounds produced by blasting caps. The caps were detonated from a vessel anchored at three different locations along the 20 fathom contour. The vessel's locations were determined with the range finder-pelorus method used earlier. The position obtained for hydrophone B, Figure 14, differs considerably from the positions obtained earlier and is believed to be more reliable than the earlier observations. The location of hydrophone A was confirmed to within some 100 yards.

It is planned to make further determinations of the hydrophone positions with blasting caps. The location of the vessel from which the caps are detonated will be obtained by range and bearing observations as before but with better equipment. With care, it should be possible to locate the hydrophones to within 100 feet.

The bottom contours shown in the figure were obtained with R/V GERDA on June 12 and 13, 1960.[1] The ship's position was obtained from radar range and bearing observations on the Bimini shore line. The contours on Figure 14, have been shifted 375 yards to the west of corresponding contours shown in the referenced memorandum. The shift was made to bring the contours into line with the range and depth observations that were made when the cable was installed. The resulting profile along the direction of the cable path (289°T) is shown in Figure 15. It is believed that the new positions of the contours, which were shifted as a group, are reasonably good representations of depth versus range and bearing from a mid-point on the shore line of the Lerner Marine Laboratory property.

8. Preliminary Results.

(a) Marine Animal Sounds

It was possible to obtain useful, sustained recordings beginning with the second week in February, 1961. Prior to this date, cursory observations indicated overloading due to what appeared to be direct contact with the shallow water hydrophone. Two divers descended to the hydrophone, took movies of the area, and covered the cable and the hydrophone with sand. The movies revealed that a small fish of the family Labridae was making direct contact with the protective cage of the hydrophone. With the aid of the movies it was possible to identify the presence of other fish in close proximity to the hydrophone. These were members of the Carangidae, *Seriola* sp., and a single grunt, *Haemulon album*. Using skin diving techniques, approximately 35 species of teleosts and three species of elasmobranchs were noted in the area which is landward of the shallow water hydrophone. It was in this general area that portable listening gear and glass bottom buckets were used to hear and see several species of reef fishes.

Under the present sampling program, sustained recordings are being made for 48 hours duration. Between recordings three days are scheduled for monitoring and for adjustments in the system. Since a two track recorder is being used, it is possible to record and monitor Channel A and Channel B (shallow and deep water hydrophones respectively) at the same time. Monitoring is usually done at a playback speed of eight times the normal recording speed of 1 7/8 inches a second.

The sounds are grouped into categories on the basis of similarity of aural characteristics. The names given the categories

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[1] Cruise Report -- Cruise G-6015, R. Dann, September 7, 1960

are intended to be somewhat descriptive of the sound and do not infer the source. To date, 26 categories have been noted. New sounds are being heard each week, while concurrently some of the earlier ones are no longer heard. For example, the "Grunts" were heard in December 1960 and January 1961, but have not been heard since that time. "Bursts" were common until the last of December, but have been steadily diminishing. The "Moo", first heard on 21 February 1961 is now an extremely frequent sound as is the "Tuba" which was first recorded on 1 March 1961.

To date no concerted effort has been made to identify the sound producers; however, plans are underway for several methods to do this.

Preliminary data concerning the frequency of occurrence of the sound categories are shown in Figures 16, 17, and 18. It appears (Figure 16) that some of the sounds show a diurnal pattern. The "A" Pop, for example, consistently shows a somewhat greater night than daytime activity but the "B" Honk shows a tendency toward greater daytime activity. The "A" Honk fails to show a diurnal pattern.

Considering the occurrence of a single sound category in four hour intervals, it can be seen (Figures 17 and 18) that there is some tendency toward a pattern of soniferous activity for the 24 hour periods. Both the "A" Honk and the "B" Roar exhibit reduced activity about 4:00 a.m.

Because of the short time period which has elapsed since the first sustained recording, it is not possible to generalize on seasonal variation. However, a continued increase of the overall sonic activity has been noted in the area of the two hydrophones. For one or two sounds, it is possible that this is due to an accompanying increase in aural acuity of those doing the monitoring.

(b) Ambient Noise

Preliminary results of the measurement of broad band ambient noise levels on a diurnal basis, are shown in Figures 19 and 20. The averages of the observations for the seven days, are shown on the bottom chart of Figure 20. There appears to be a slight diurnal pattern exhibited by a small increase in the average level at 0200 hours and a slight decrease at 1500 hours. It is planned to investigate this further employing selected frequency bands and continuously observing wind speed and direction and tide heights. The noise levels at the shallow and deep hydrophones, averaged over 24 hours, are respectively, 1.7 and -0.5 db μb.

The above level measurements were obtained with the aid of Esterline Angus milliameter chart recorders. Short sections of the noise level charts are shown in Figures 21 and 22. Levels were read at hourly intervals from the lower edge of the traces. The irregularly occurring level increases having durations of several minutes to several hours are caused by passing boats and ships. Such increases were excluded from the above noted preliminary results by using the mean of the levels before and after the increase.

Short duration increases, less than some 15 minutes, are produced by small boats, mostly fishing vessels. The longer ones are produced by passing ships, usually tankers and freighters. To produce an increase of 3 db or more, it is estimated that small boats pass within a distance of a half mile from the hydrophone. The corresponding distance for ships is some 2 to 5 miles. Because ships usually pass seaward of the deep hydrophone and the recorder has a linear scale, large deflections on the deep hydrophone chart often correspond to hardly noticeable deflections on the chart of the shallow hydrophone although it is only a mile inshore from the deep hydrophone. The spikes that rise above the mean noise level trace are short pulses of sound such as are produced by marine animals. They consistently occur more frequently on the shallow than on the deep hydrophone.

The number of occurrences of increases caused by small boats that exceeded 3.0 db, are shown in the upper chart of Figure 23. The number is the average, over seven days, of the total occurrences in night and day periods of 12 hours each. A small boat passed by about once every two hours in daytime. During night time, there was little activity. Corresponding occurrences of the longer duration increases attributable to ships, are shown in the lower chart of Figure 23. As might be expected, the difference between day and night activity is less than that for small boats.

(c) Propagation

A series of propagation tests, using one half pound dynamite charges, were made during the period 27 April to 5 May, 1961.[2] The charges were electrically detonated at depths of 5 feet and 15 feet and at distances of 2.5 to 43.0 nm from the hydrophones. The received levels were measured with a Sanborn chart recorder employing a log-amplifier. The build up time of the recorder was 0.01 seconds and the levels were based on the maximum deflections. A source level of 124.0 dbμd at 1 yard, was calculated for the shot at 2.5 nm, assuming spherical radiation. On this basis, the transmission loss across the Gulf Stream, from Fowey Rocks to Bimini, a distance of 43 nm, was 110 db. The corresponding loss for spherical spreading is 98 db.

The levels received at the deep and shallow hydrophone were about the same. The appearance of the arrivals however, was quite different.

It is planned to make a more complete study of the possible transmission paths and the spectrum levels of the received pulses by means of magnetic tape recordings.

Sound velocity versus depth profiles and the bottom profile from Fowey Rocks to Bimini and from Virginia Key to Bimini were measured

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2 Propagation Tests Across the Gulf Stream, Memorandum for File, May 25, 1961, W. C. Green.

during the propagation tests.[3,4] These are shown in Figures 24, 25, 26, and 27. The velocity-depth profiles of Figure 24 were taken at the locations shown in Figure 25. From both a theoretical and experimental sound transmission viewpoint, this section of the Straits of Florida presents the following interesting features:

1. A somewhat uncertain surface channel.
2. A thermocline that progressively deepens from west to east.
3. A downward refracting medium below the thermocline.
4. A two section bottom profile comprising a half depth and a full depth section.
5. The possibility of internal waves along the thermocline.

It is hoped that it will be possible to study propagation across the Straits in relation to oceanographic parameters, on a continuous basis. This will require a sound source on the west bank roughly equivalent to a half pound charge, and means on both the west and east banks to continuously measure temperature versus depth and surface wave height. Measurements on a continuous basis through diurnal, seasonal and weather cycles will provide a type of information that has not been available before, for evaluating theoretical procedures.

The Marine Laboratory
Institute of Marine Science
University of Miami
June 26, 1961

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[3] Bottom Profiles, Miami to Bimini, Memorandum for File, May 29, 1961, John Schenck

[4] Sound Velocity versus Depth Profiles, Florida Straits, Memorandum for File, June 13, 1961, John Schenck

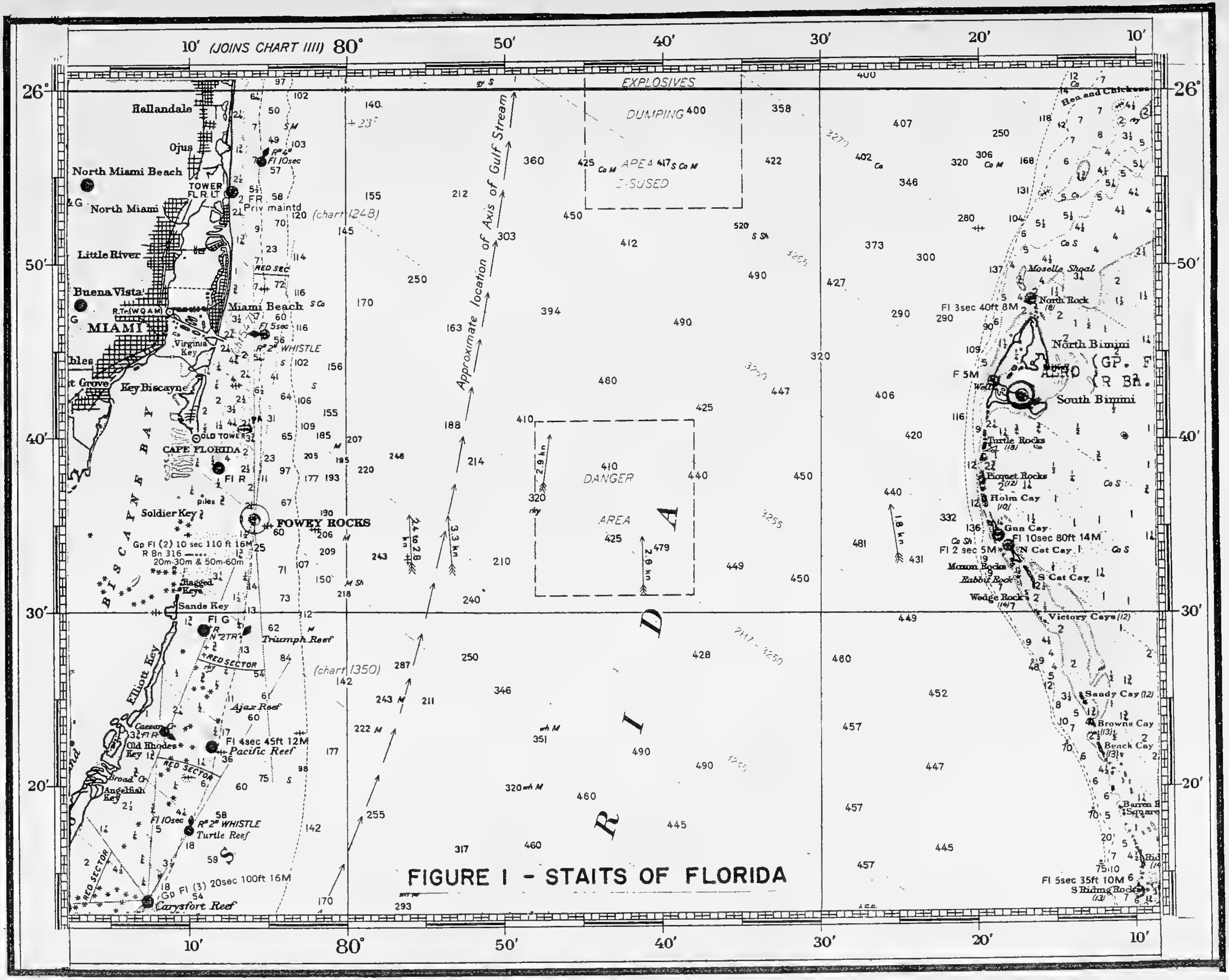
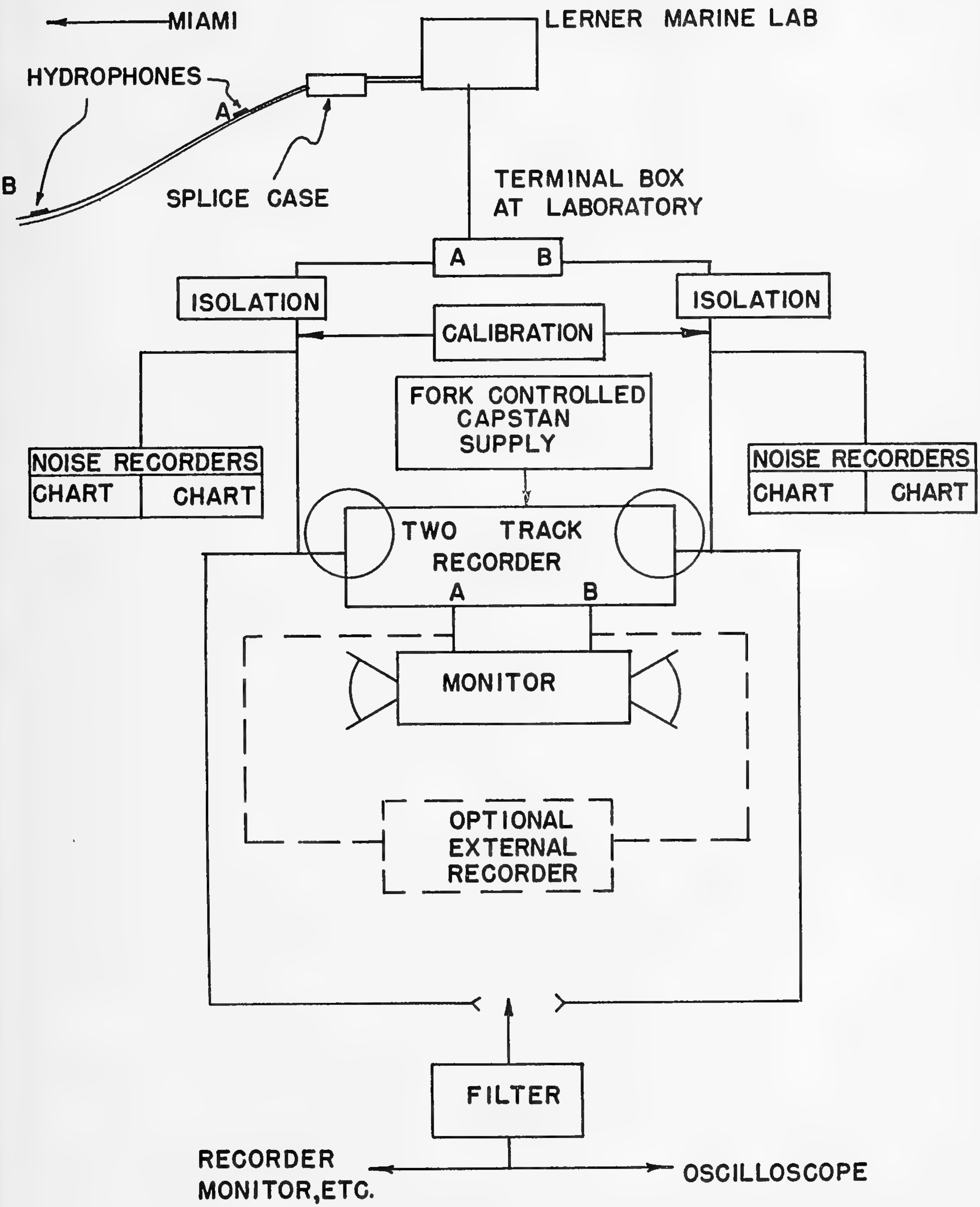
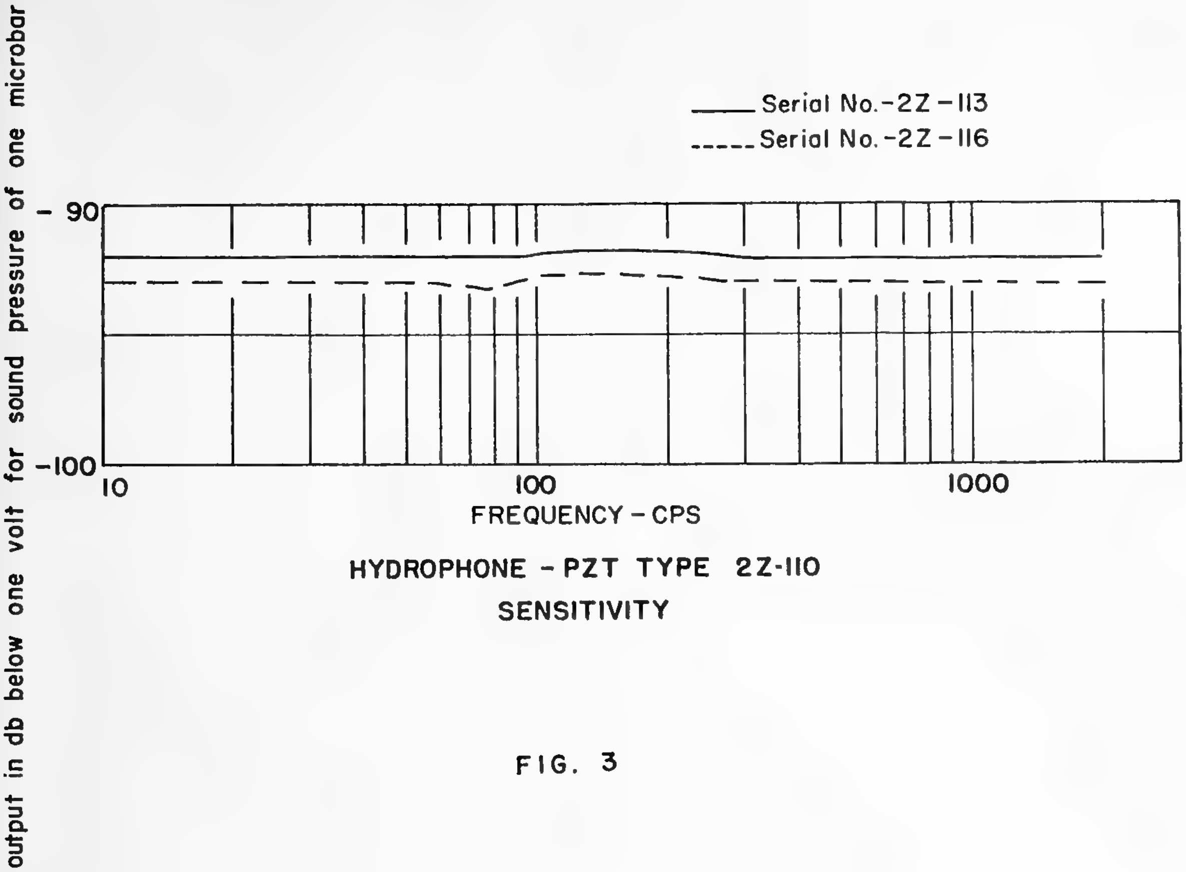


FIGURE I - STAITS OF FLORIDA



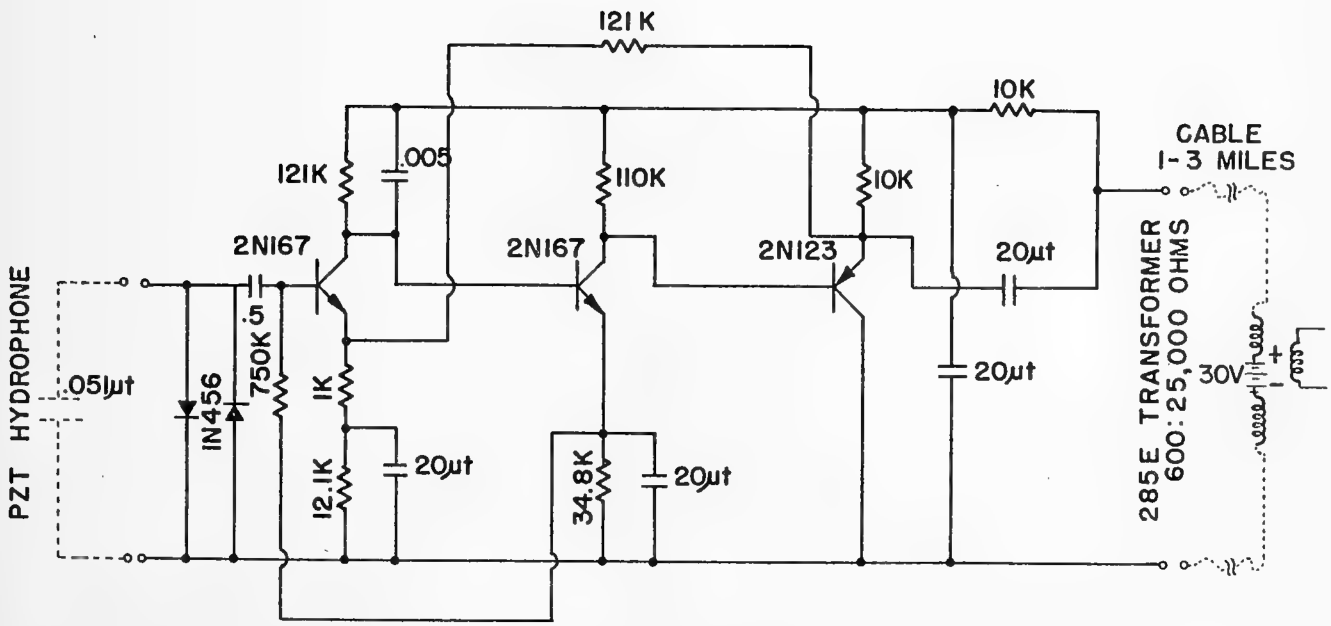
SYSTEM DIAGRAM LABORATORY EQUIPMENT

FIG. 2



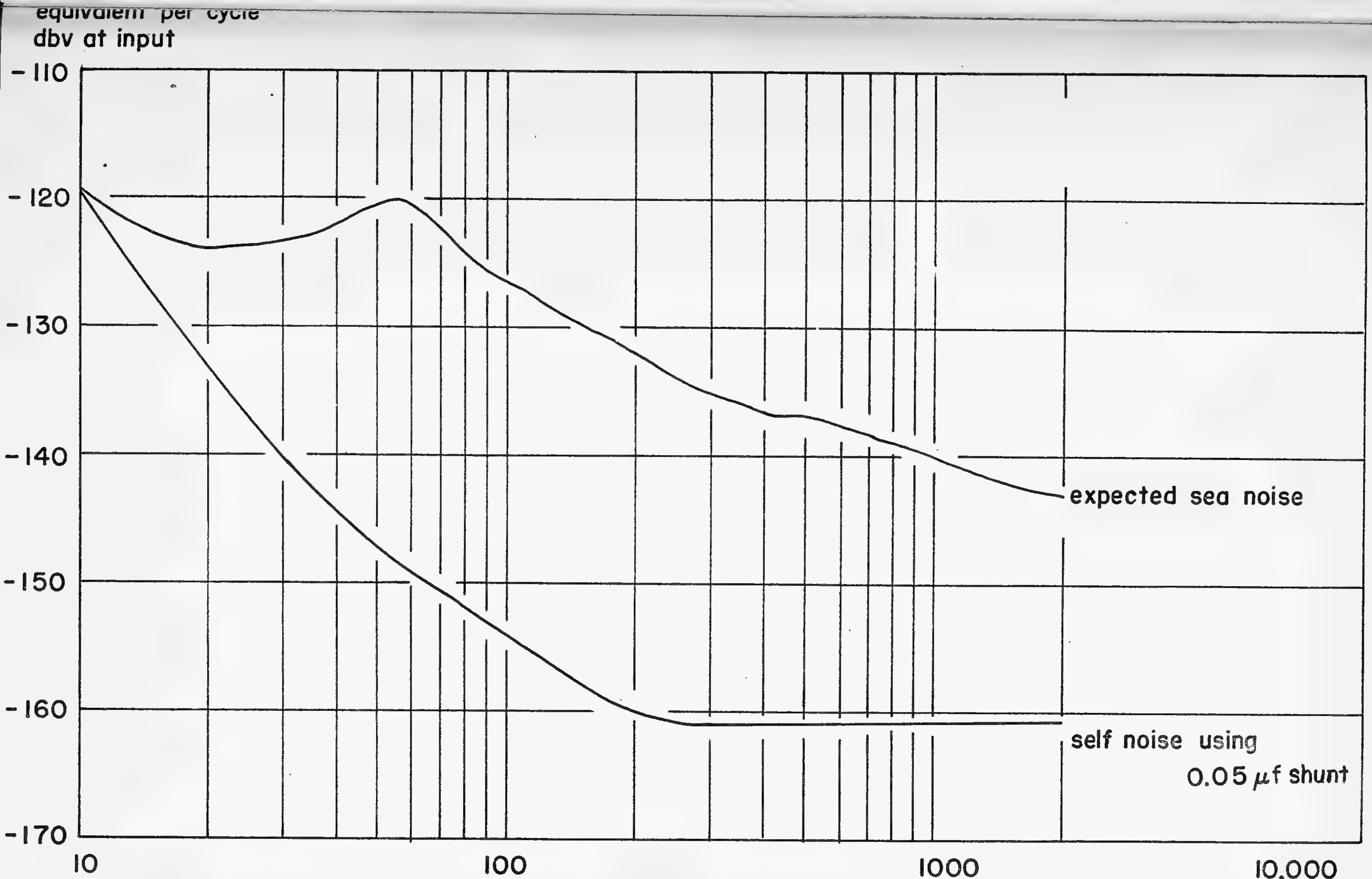
HYDROPHONE - PZT TYPE 2Z-110
SENSITIVITY

FIG. 3



HYDROPHONE PREAMPLIFIER
SCHEMATIC

FIG. 4



PREAMPLIFIER SELF NOISE

FIG. 5

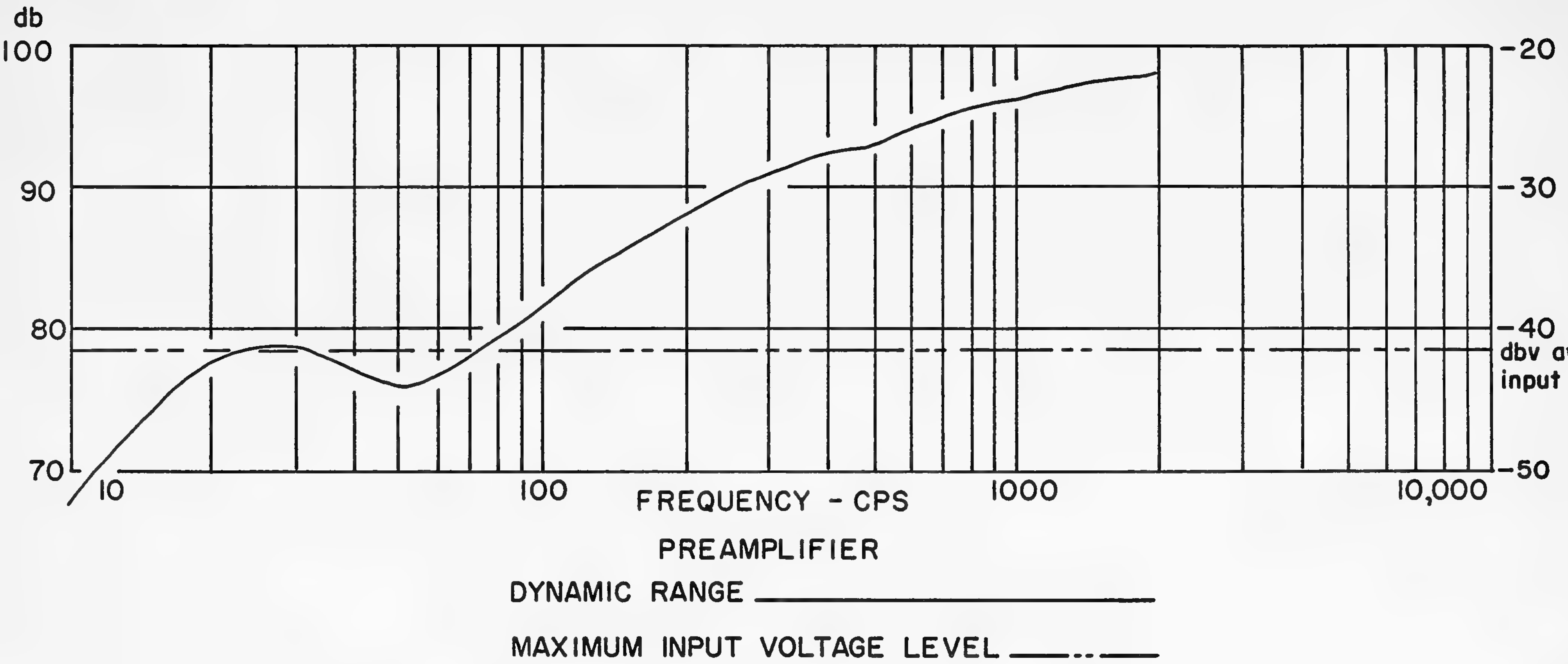
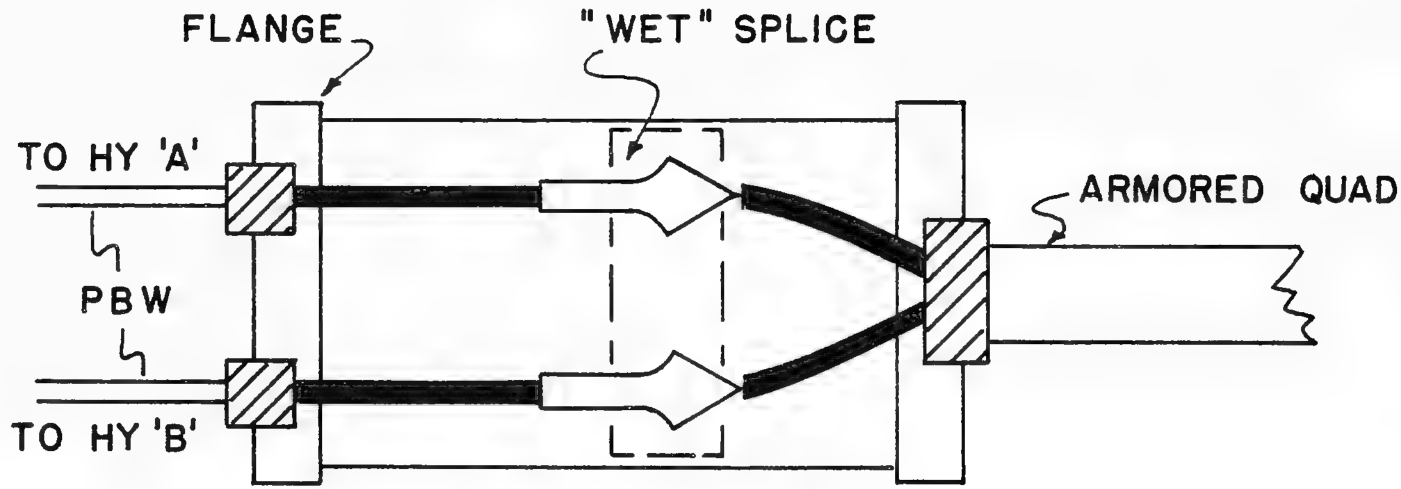

db
100
90
80
70
-20
-30
-40
dbv at
input
-50
10
100
1000
10,000
FREQUENCY - CPS
PREAMPLIFIER
DYNAMIC RANGE
MAXIMUM INPUT VOLTAGE LEVEL

FIG. 6



SPLICE CASE

FIG. 7

BIMINI HYDROPHONE INSTALLATION
LABORATORY EQUIPMENT

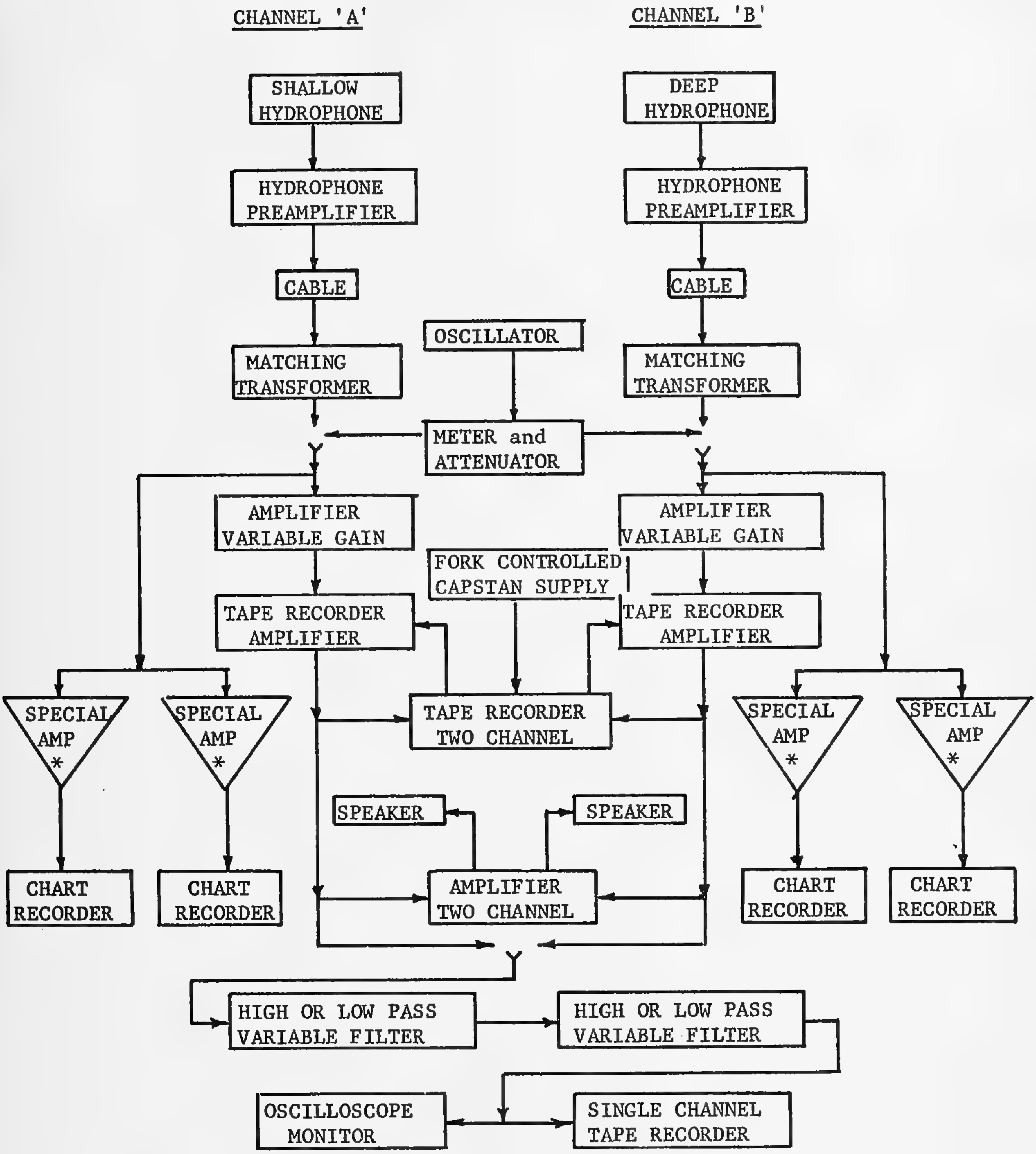
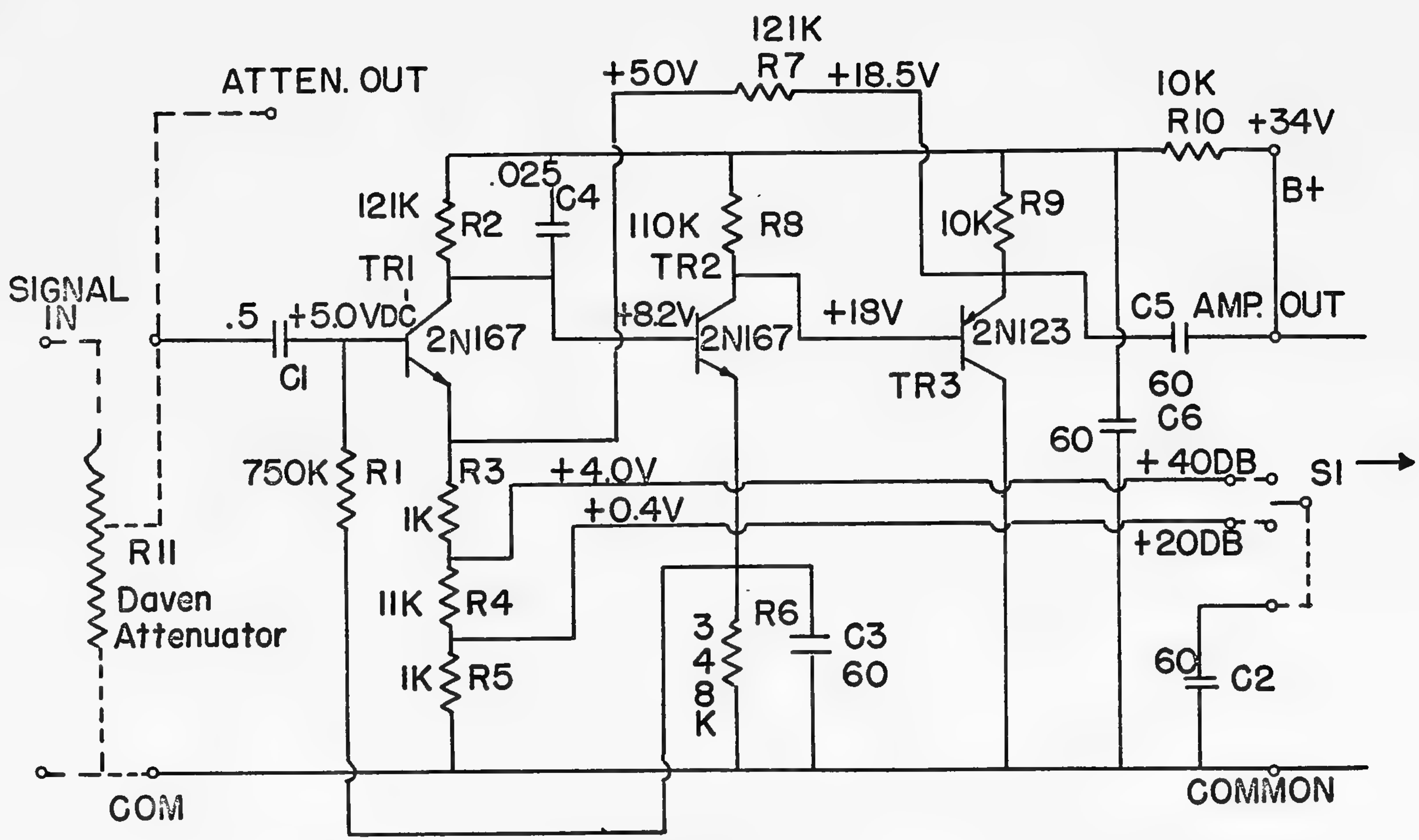


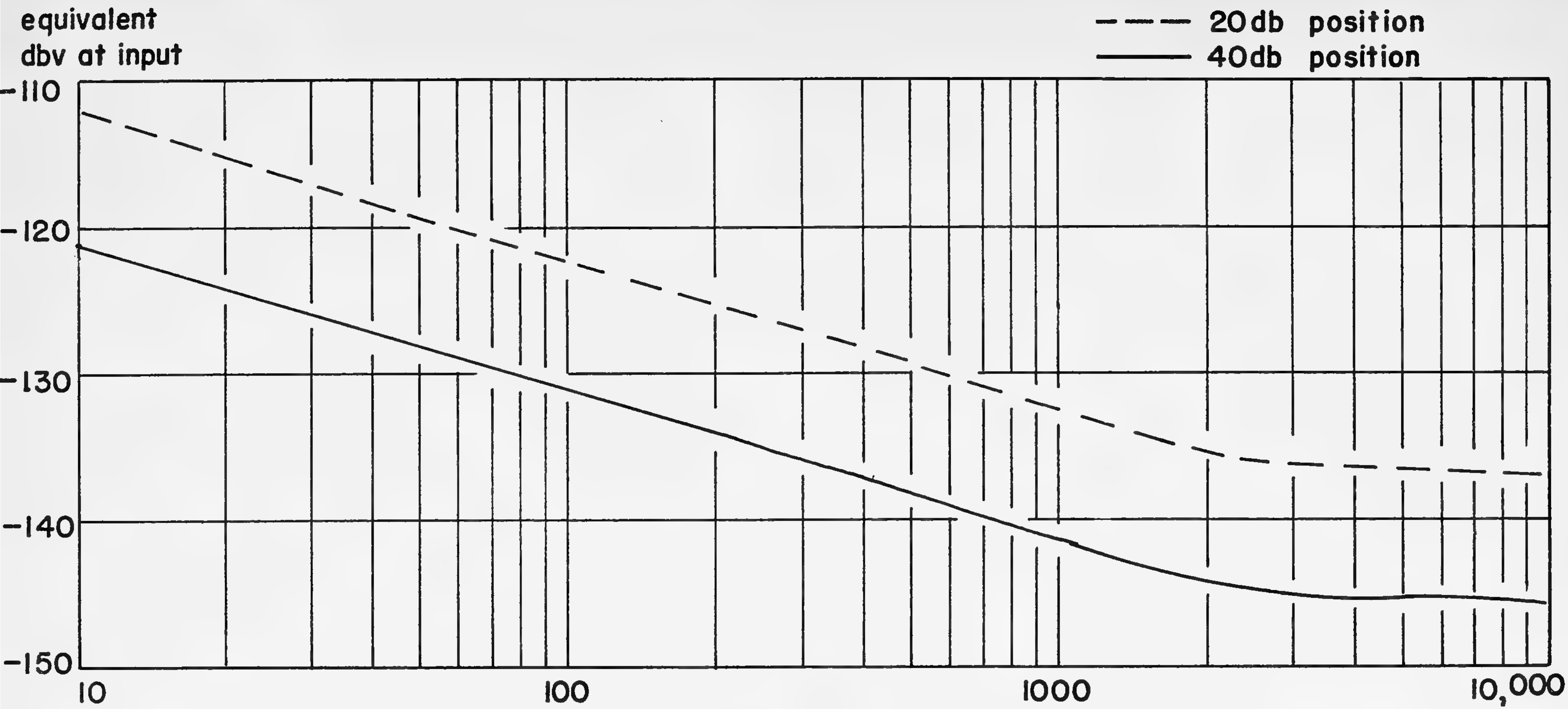
FIG. 8

TERMINAL AMPLIFIER



ALL CAPACITANCE IN MICROFARADS

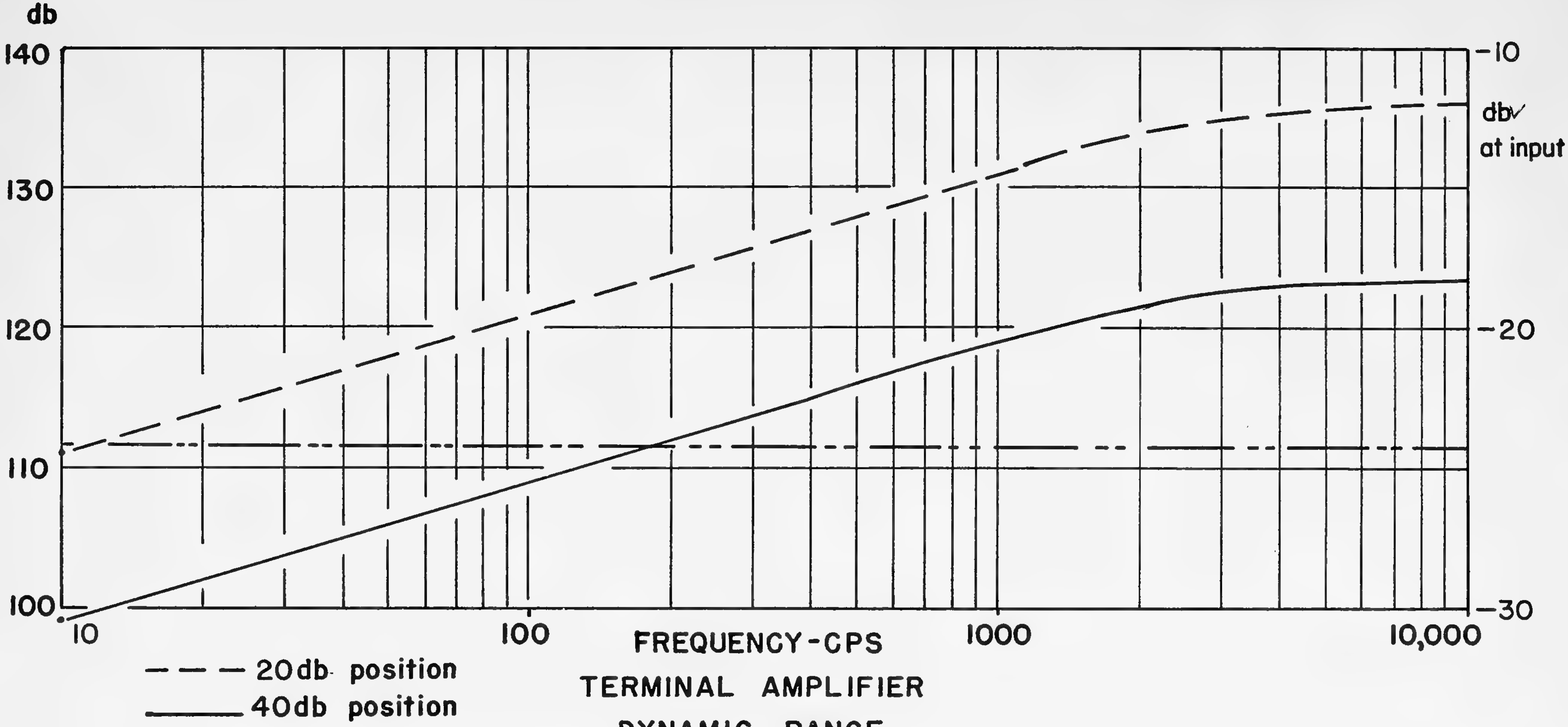
FIGURE 9



TERMINAL AMPLIFIER

self noise per cycle (with input attenuator)

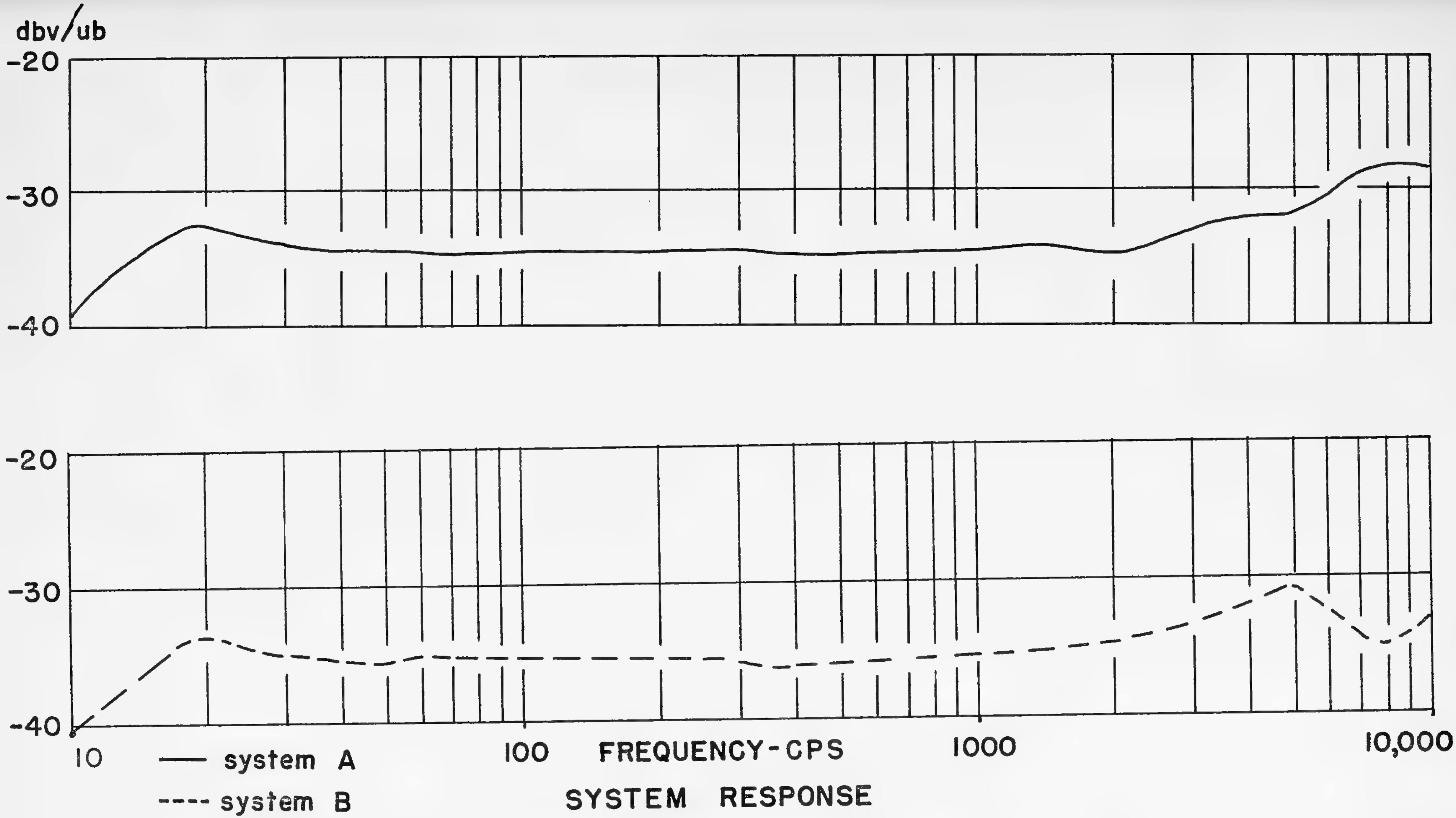
FIG. 10



TERMINAL AMPLIFIER
DYNAMIC RANGE

MAXIMUM INPUT VOLTAGE FOR OVERLOAD

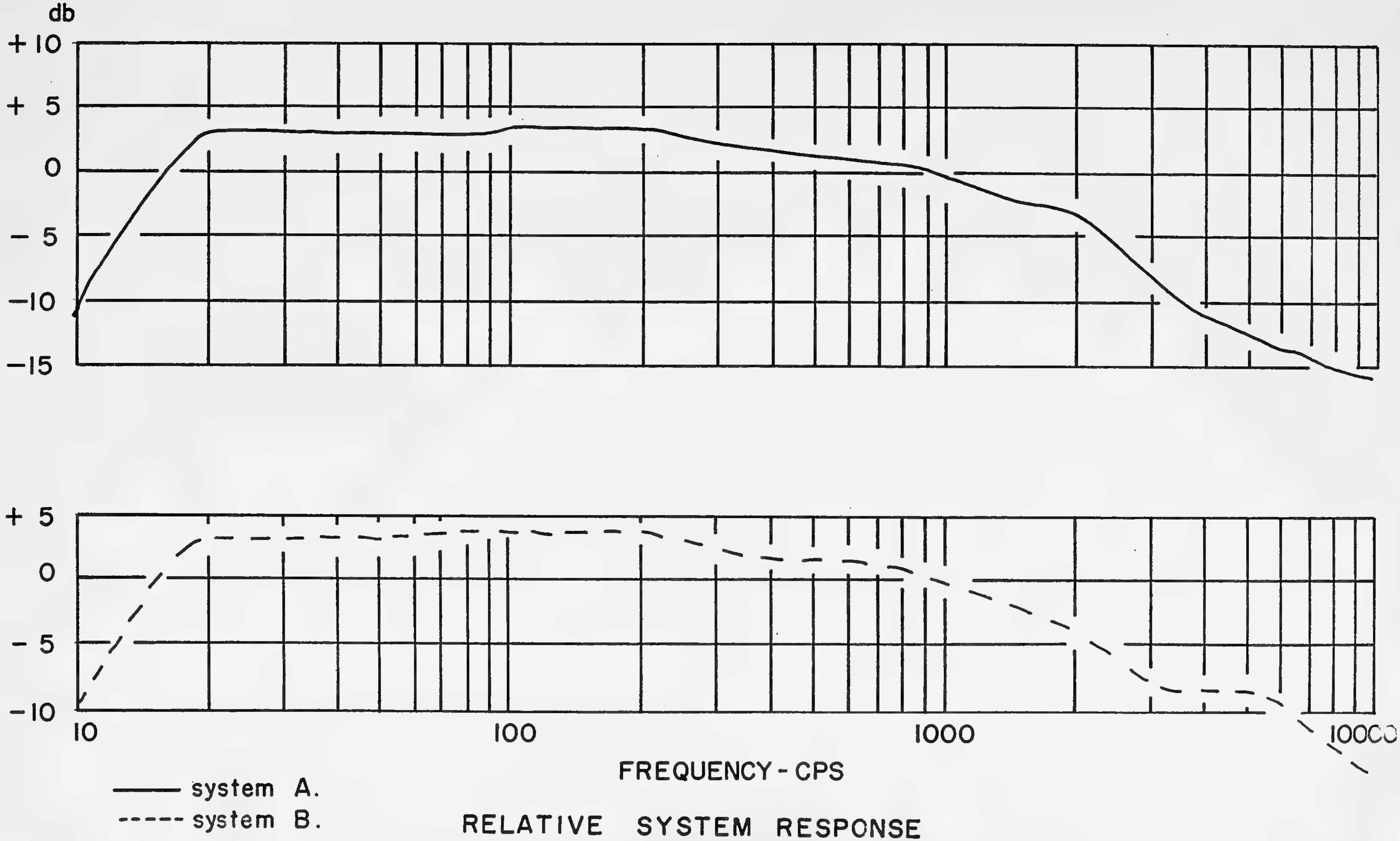
FIG. 11



SYSTEM RESPONSE

1 ub at hydrophone to dbv at terminal amplifier input

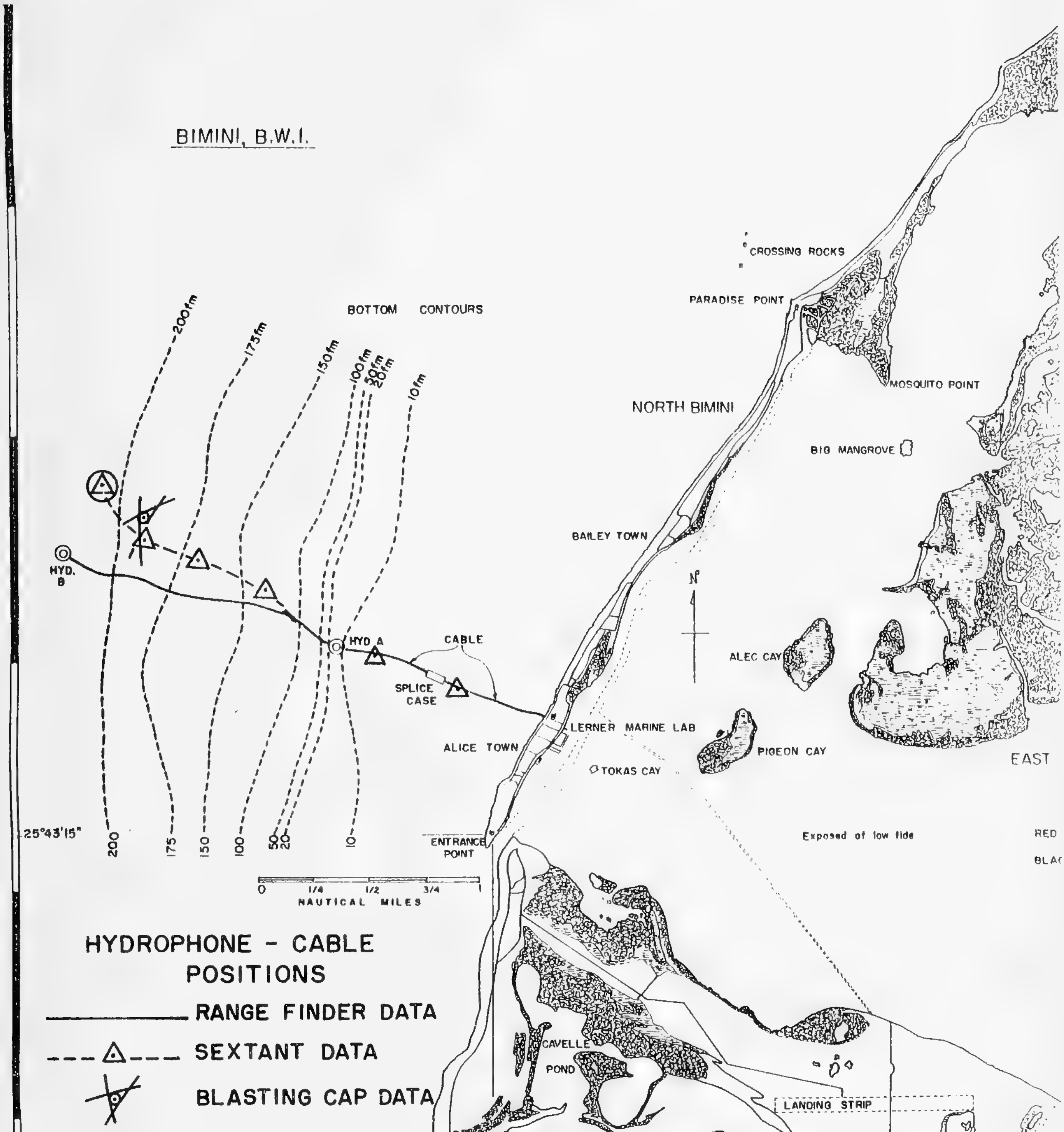
FIG. 12



RELATIVE SYSTEM RESPONSE

including record-reproduce loss for a tape speed of $1\frac{7}{8}$ ips

FIG. 13



RANGE AND BEARING FROM LERNER LABORATORY

HYD. A --- 0.97 NM 290°T

HYD. B --- 1.95 NM 298°T

(BLASTING CAP DATA)

FIG. 14

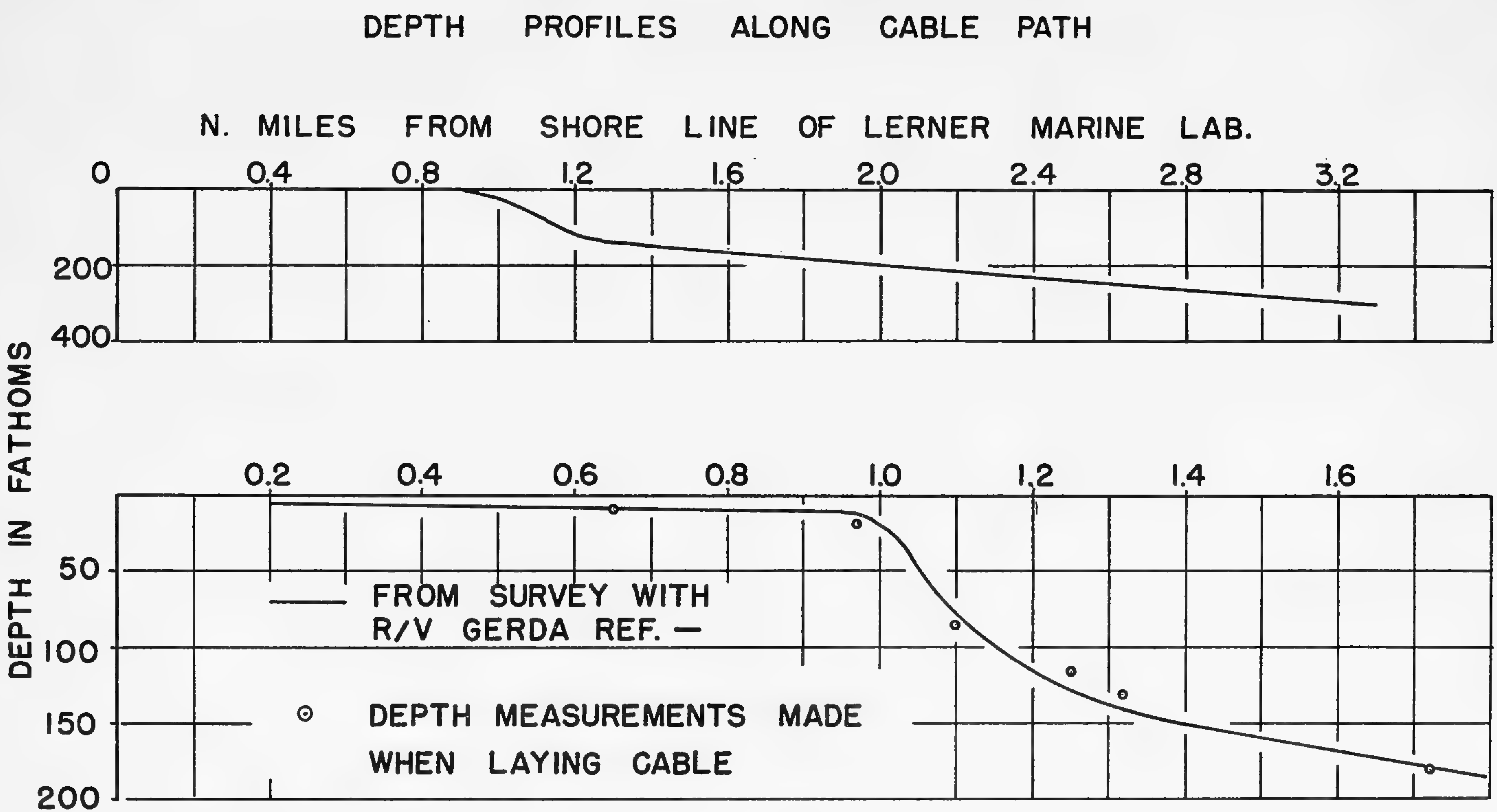

DEPTH PROFILES ALONG CABLE PATH
N. MILES FROM SHORE LINE OF LERNER MARINE LAB.
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
200
400
DEPTH IN FATHOMS
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
50
100
150
200
FROM SURVEY WITH
R/V GERDA REF. —
DEPTH MEASUREMENTS MADE
WHEN LAYING CABLE

FIG. 15

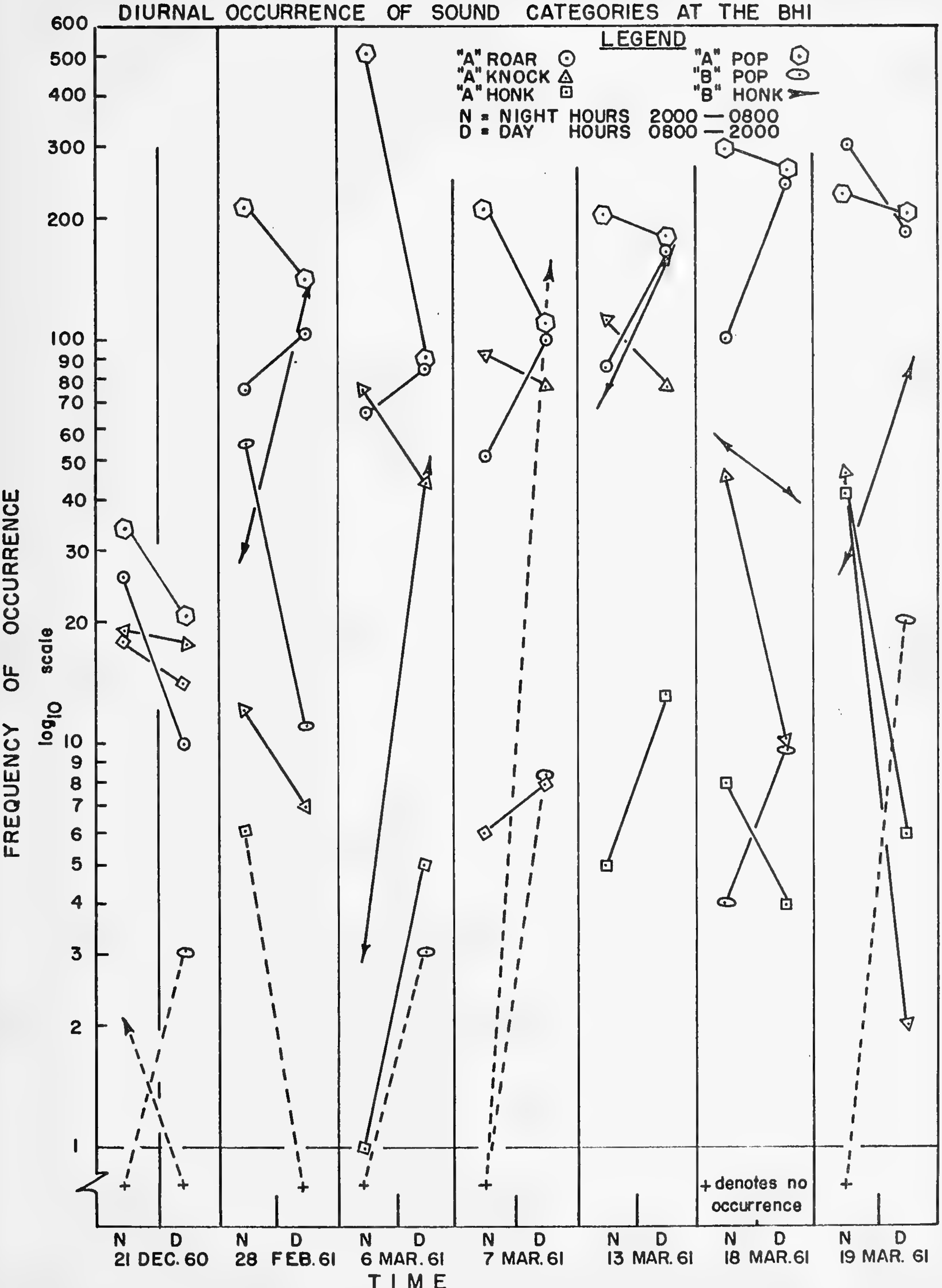

DIURNAL OCCURRENCE OF SOUND CATEGORIES AT THE BHI
LEGEND
"A" ROAR
"A" KNOCK
"A" HONK
"A" POP
"B" POP
"B" HONK
N = NIGHT HOURS 2000 — 0800
D = DAY HOURS 0800 — 2000
FREQUENCY OF OCCURRENCE
log10 scale
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
+ denotes no occurrence
N D
21 DEC. 60
N D
28 FEB. 61
N D
6 MAR. 61
N D
7 MAR. 61
N D
13 MAR. 61
N D
18 MAR. 61
N D
19 MAR. 61
TIME

FIG. 16

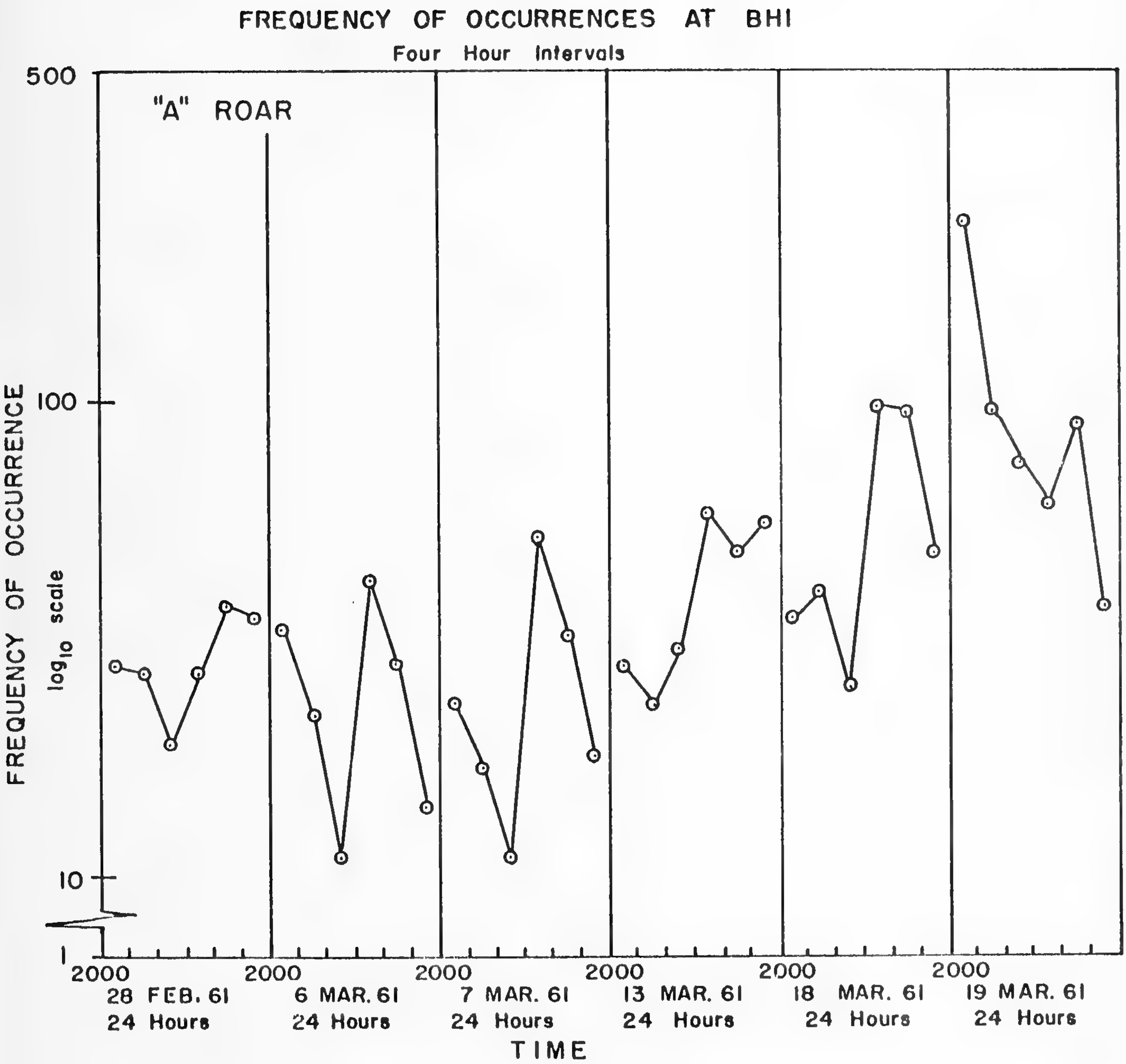

FREQUENCY OF OCCURRENCES AT BHI
Four Hour Intervals
"A" ROAR
500
100
10
1
FREQUENCY OF OCCURRENCE
$\log_{10}$ scale
2000
28 FEB. 61
24 Hours
2000
6 MAR. 61
24 Hours
2000
7 MAR. 61
24 Hours
2000
13 MAR. 61
24 Hours
2000
18 MAR. 61
24 Hours
2000
19 MAR. 61
24 Hours
TIME

FIG. 17

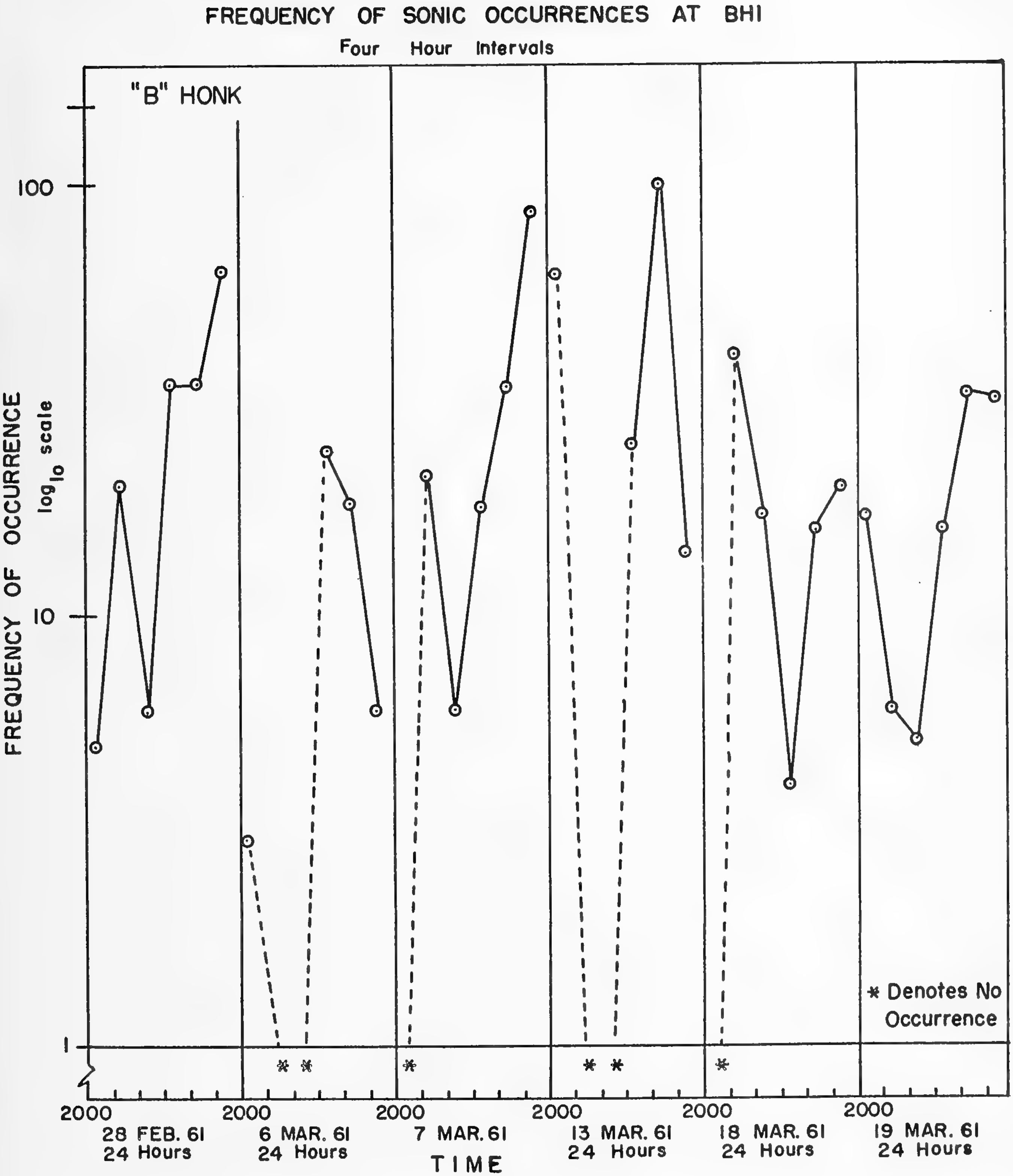
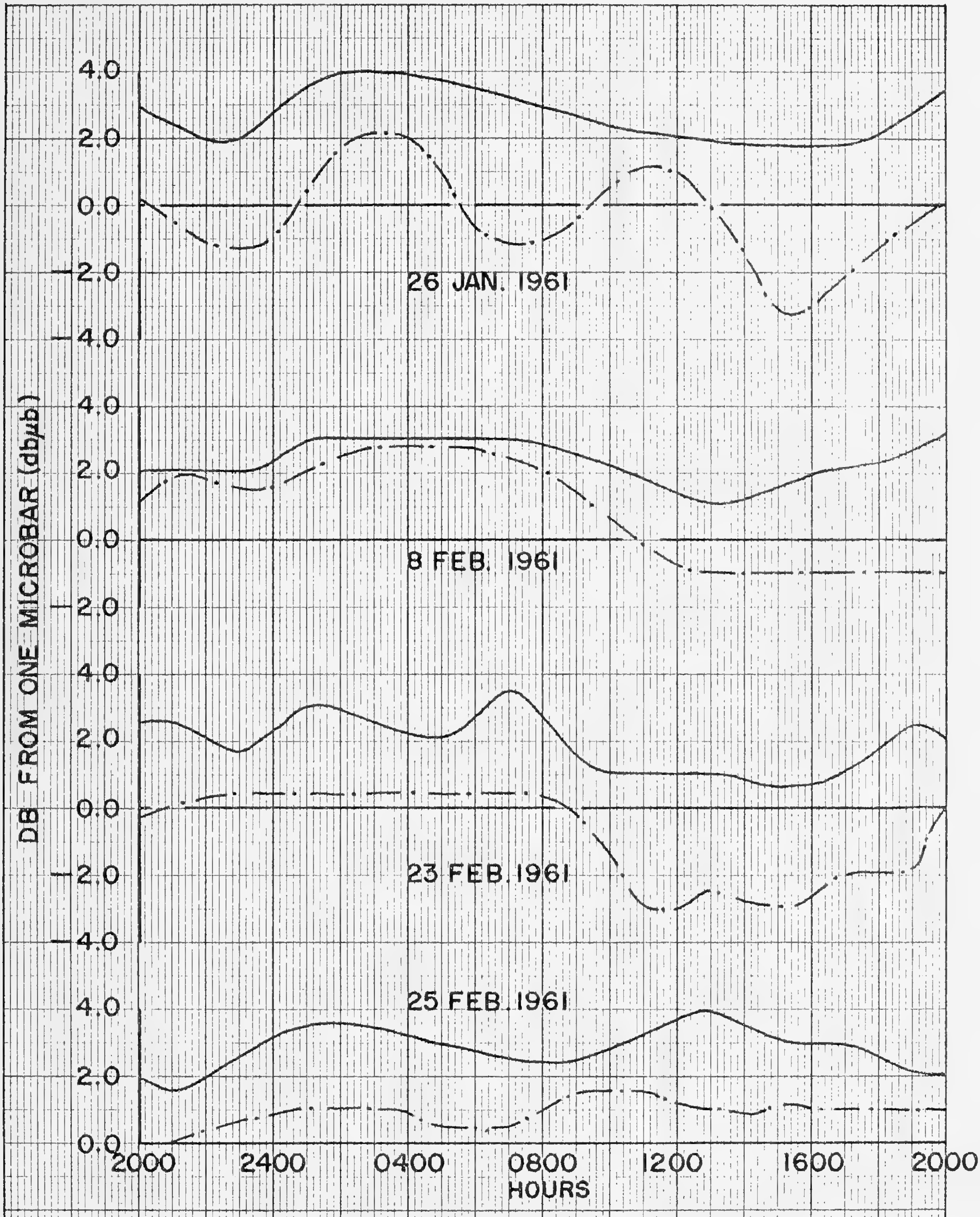

FREQUENCY OF SONIC OCCURRENCES AT BHI
Four Hour Intervals
"B" HONK
100
10
1
FREQUENCY OF OCCURRENCE
$\log_{10}$ scale
* Denotes No Occurrence
2000
28 FEB. 61
24 Hours
2000
6 MAR. 61
24 Hours
2000
7 MAR. 61
2000
13 MAR. 61
24 Hours
2000
18 MAR. 61
24 Hours
2000
19 MAR. 61
24 Hours
TIME

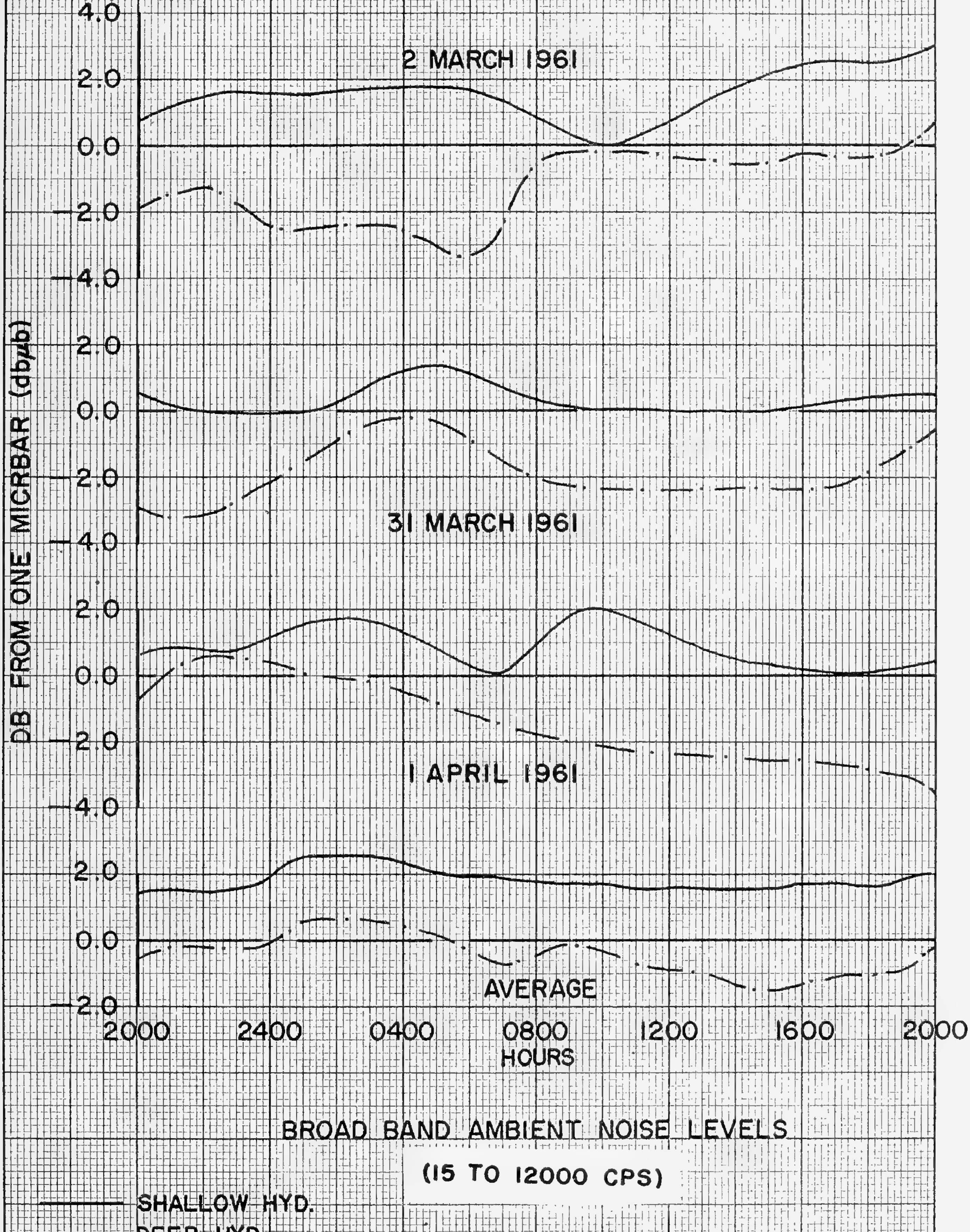
FIG. 18



BROAD BAND AMBIENT NOISE LEVELS

(15 TO 12000 CPS)

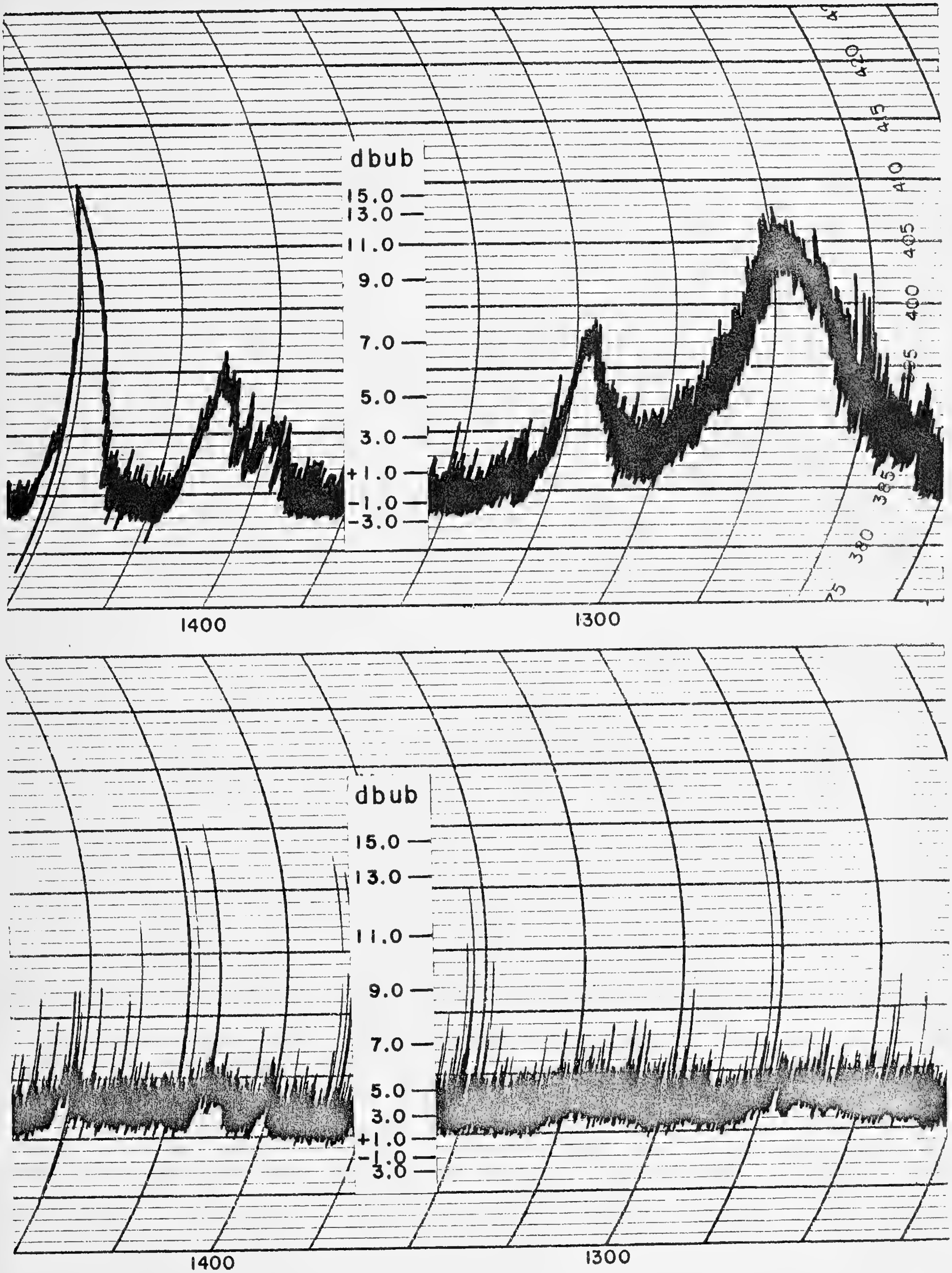
FIG. 19



BROAD BAND AMBIENT NOISE LEVELS

(15 TO 12000 CPS)

FIG. 20



HOURS – 24 FEB. 1961

FIG. 21 NOISE LEVEL CHART UPPER – DEEP HYD.
LOWER – SHALLOW HYD.

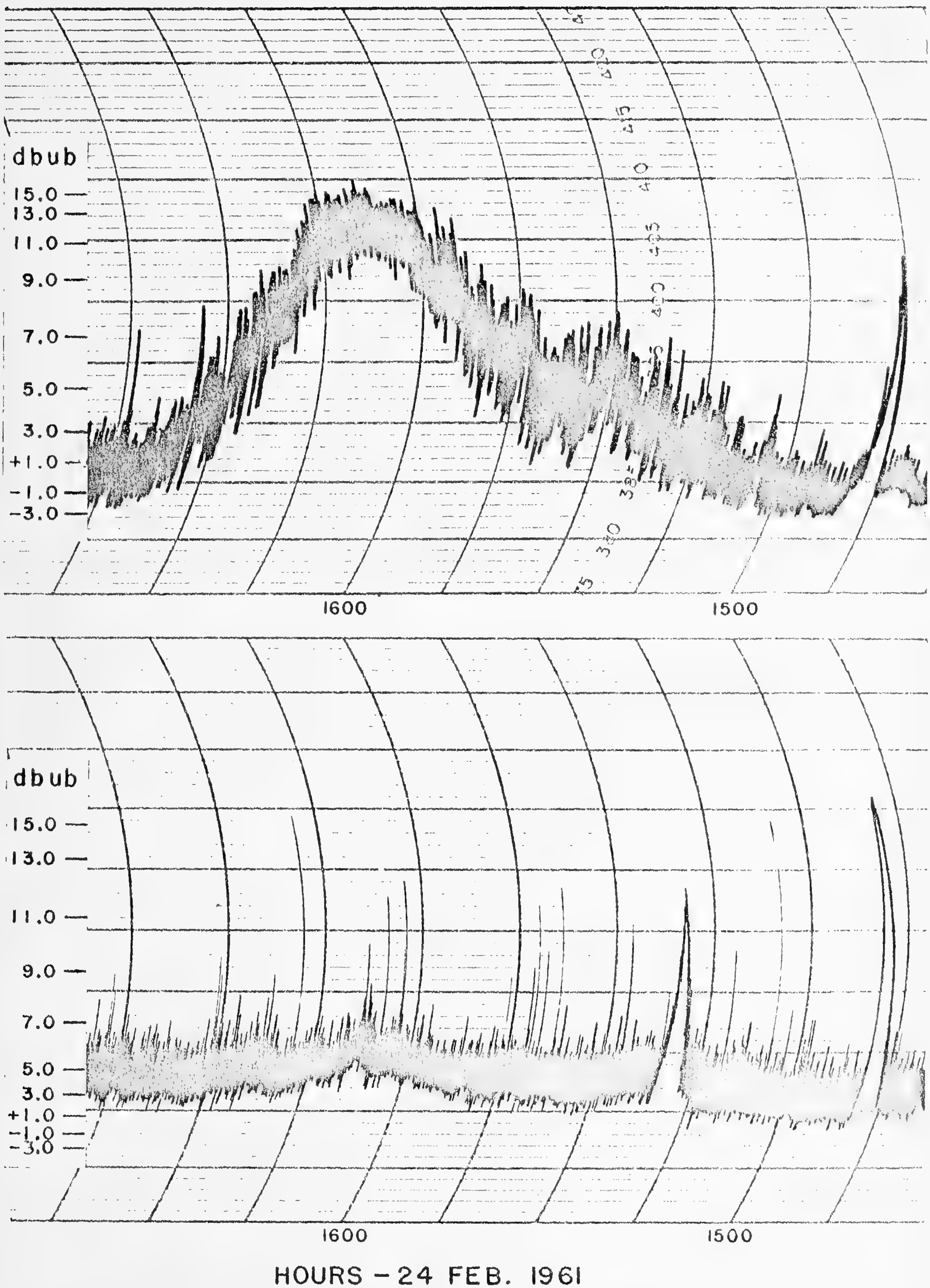


FIG. 22 NOISE LEVEL CHART UPPER - DEEP HYD.
LOWER - SHALLOW HYD.

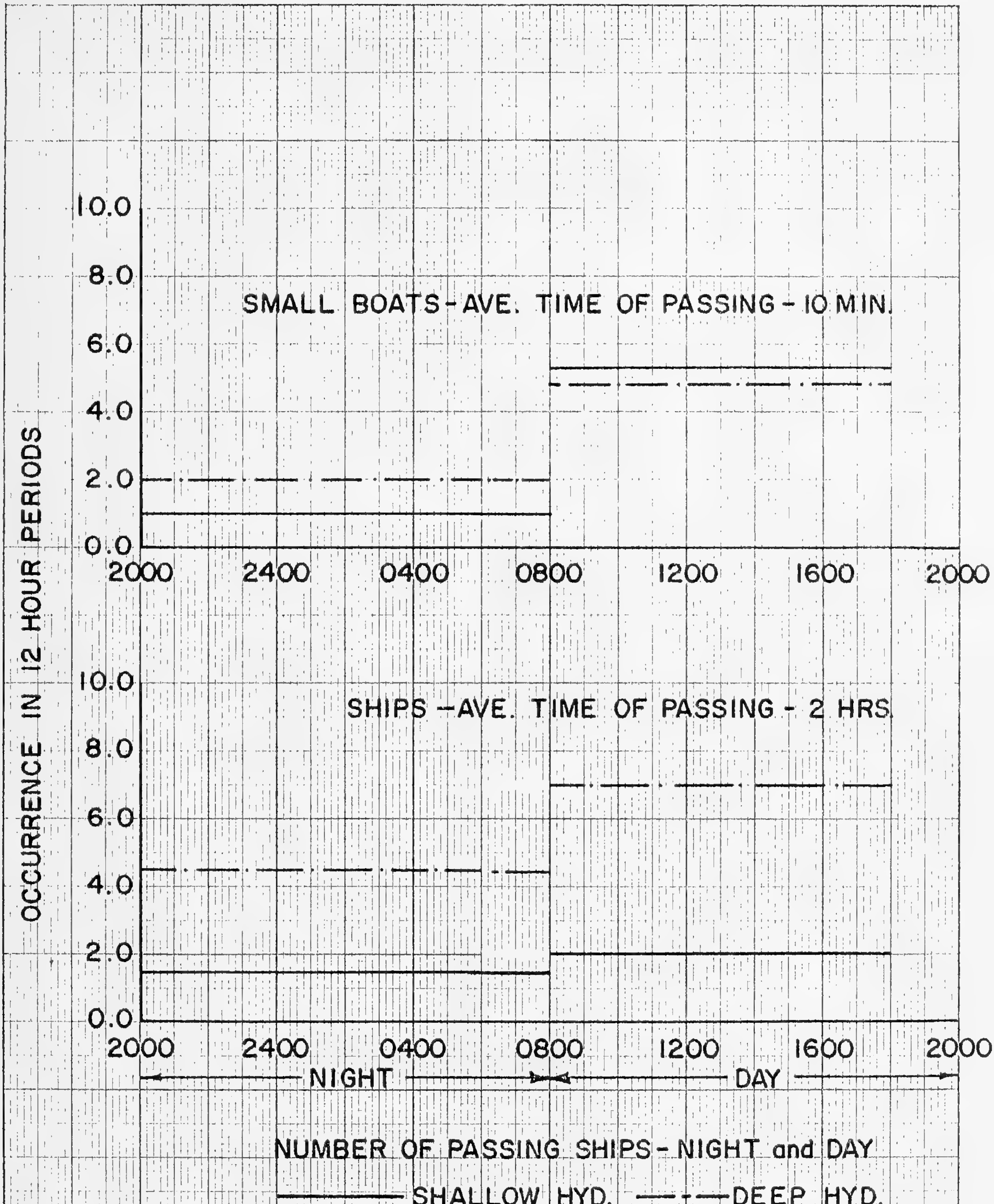
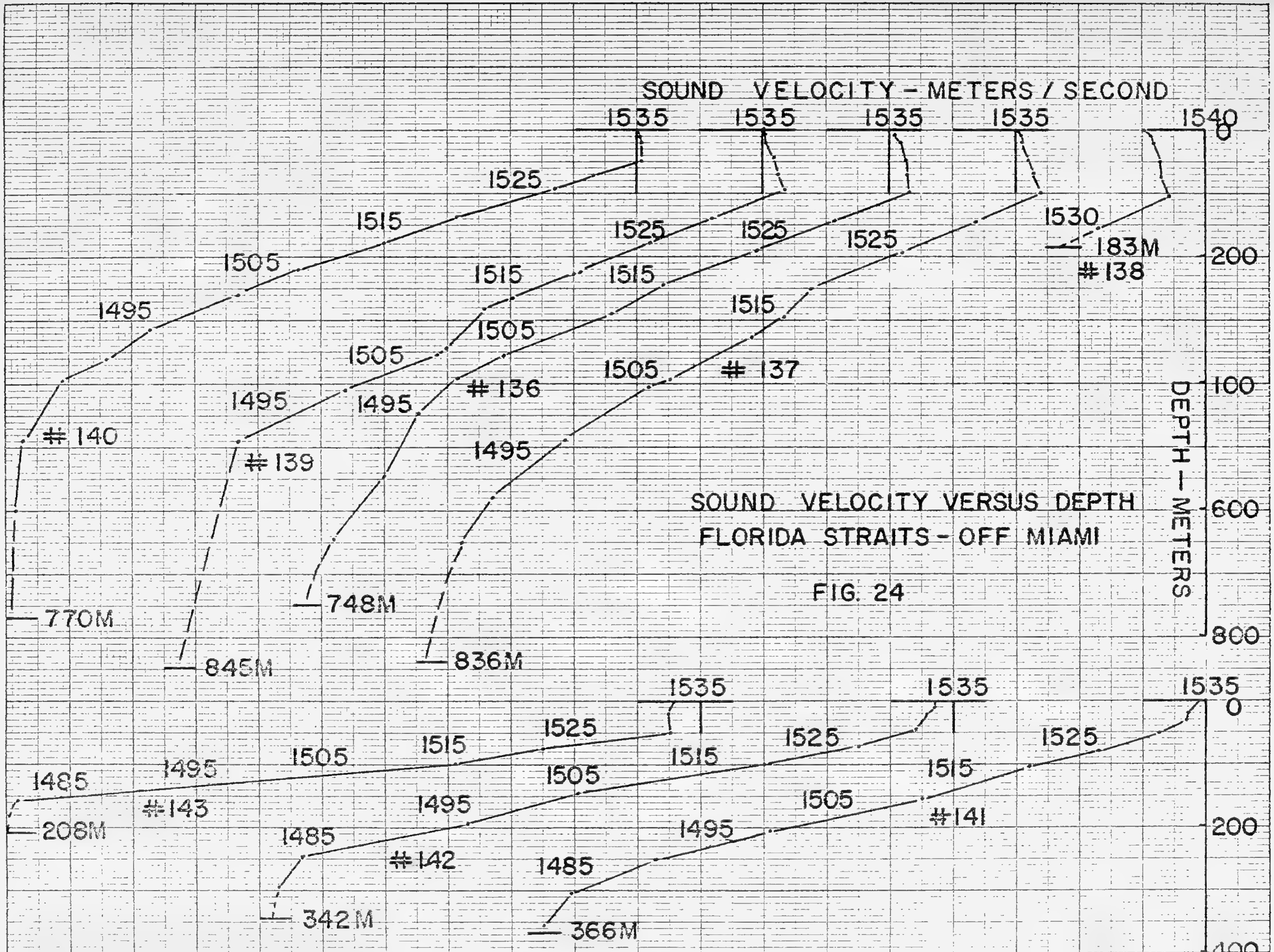

SMALL BOATS - AVE. TIME OF PASSING - 10 MIN.
SHIPS - AVE. TIME OF PASSING - 2 HRS.
OCCURRENCE IN 12 HOUR PERIODS
10.0
8.0
6.0
4.0
2.0
0.0
2000
2400
0400
0800
1200
1600
2000
NIGHT
DAY
NUMBER OF PASSING SHIPS - NIGHT and DAY
SHALLOW HYD.
DEEP HYD.

FIG. 23



SOUND VELOCITY VERSUS DEPTH
FLORIDA STRAITS - OFF MIAMI

FIG. 24

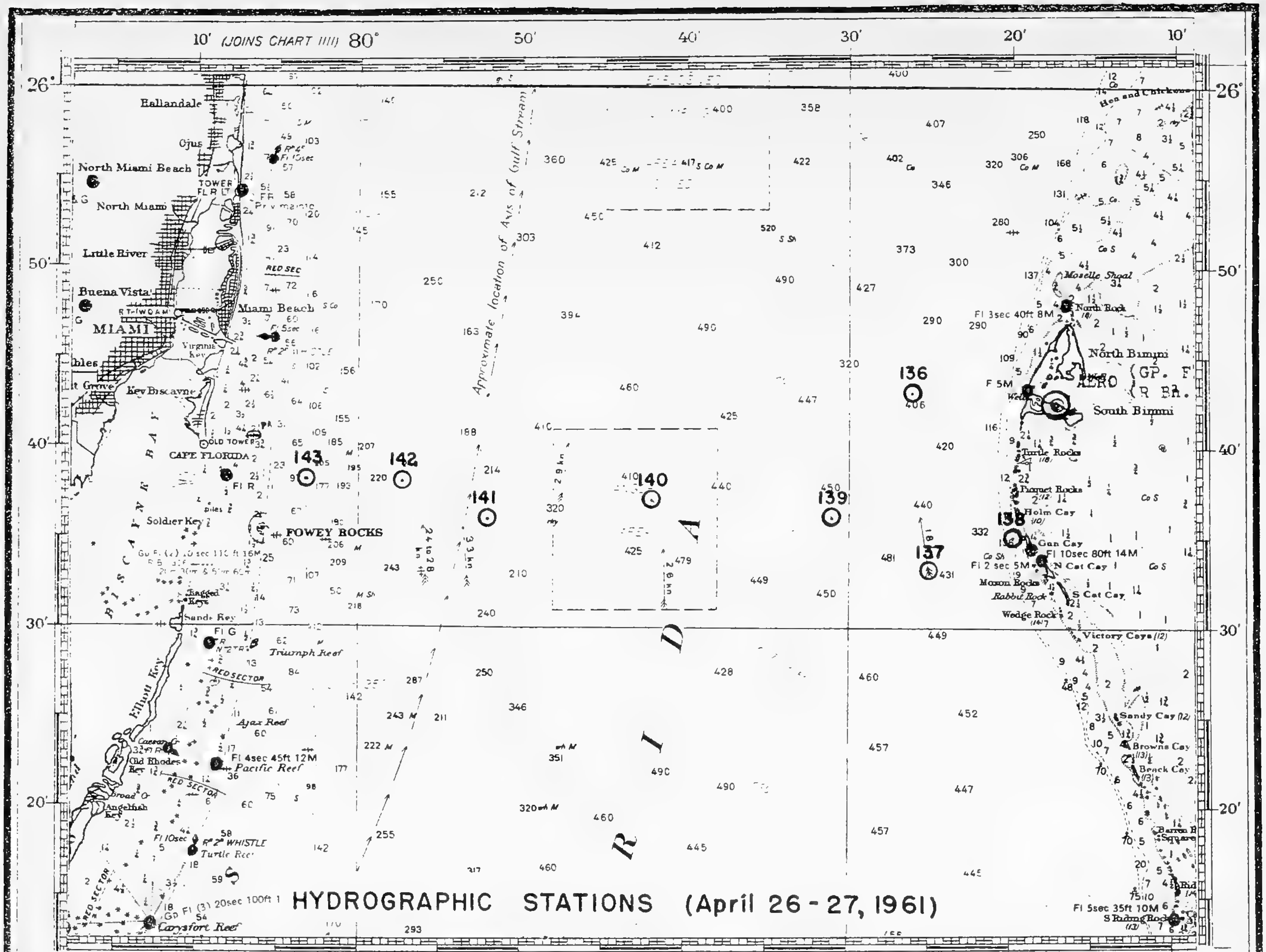


FIGURE 25 (CONTINUED 30' ON CHART 1002)

BOTTOM PROFILE

MIAMI-BIMINI ALONG 25°44'

VERTICAL SCALE 37× HORIZONTAL

FIGURE 26

BOTTOM PROFILE

FOWEY ROCKS - BIMINI

VERTICAL SCALE 37× HORIZONTAL

FIGURE 27

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